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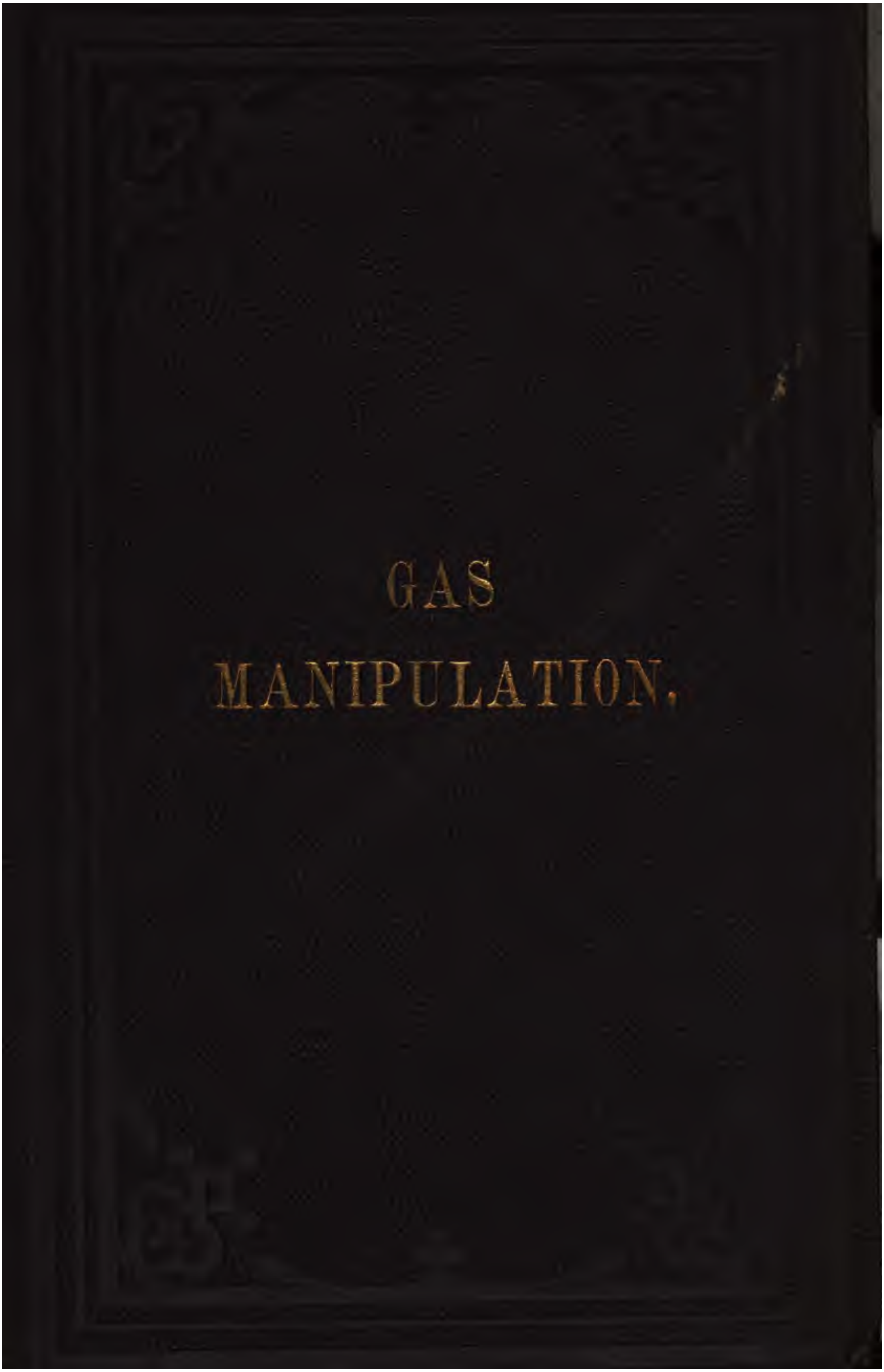

GAS
MANIPULATION.

GAS MANIPULATION.

GAS MANIPULATION,

WITH A
DESCRIPTION OF THE VARIOUS
INSTRUMENTS AND APPARATUS
EMPLOYED IN THE
ANALYSIS
OF
COAL AND COAL GAS.

BY THE LATE
HENRY BANISTER,
CHARTERED GAS COMPANY, WESTMINSTER.

ENLARGED BY
WILLIAM T. SUGG,
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BIBLIOTHECA·BODLEIANA

LONDON:
HENRY SUGG, 32, HENRIETTA STREET, COVENT GARDEN.
1867.

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BLANCHARD & SONS, PRINTERS,
MILLBANK STREET, WESTMINSTER, S.W.

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PREFACE.

THE First Edition of this work, written a few years ago by the late Mr. Banister, having for some time been out of print, it has been considered desirable, in order to meet the inquiries continually being made for it, to issue a limited impression of another, in many parts considerably enlarged; and which, it is hoped, by embracing the fullest and latest information, may be found acceptable, not only to the professional engineer, but also to the increasing numbers interested in gas legislation.

The impetus given to experimental inquiry, in consequence of the operation of the various Gas Acts, has, within a recent period, led to the invention and adoption of several methods for testing the impurities of gas, as well as its photometric power; and it is with reference to these important matters that the present Edition will, on examination, be seen to be an improvement on its predecessor.

Its new and more prominent features comprise a minute description of the following apparatus, the uses of which are either illustrated by examples, or explained by ample working details:—

The various apparatus employed for testing for ammonia —the Evans' Improved Apparatus for Testing for Sulphur— Dr. Letheby's Apparatus for Testing for Sulphur—Evans' Photometer—Dr. Letheby's Photometer, as adopted by the Corporation of London — Lowe's Jet Photometer — and, finally, Kirkham and Sugg's Self-Registering Photometer, in which the principle spoken of in the former edition of this work as a desideratum has been successfully applied.

The auxiliary instruments used with Photometers of any construction are, moreover, fully described; while the chapters on the Standard Burner and the Standard Candle are particularly copious, so as to comprise all that experience has brought to bear with reference to them. The variations so frequently found to occur when using the Standard Candle in conducting experiments, are shown to be in a great measure attributable to a defective mode of application; and suggestions, based on actual practice, are offered, the adoption of which will ensure as great an approximation to the truest results as the present Parliamentary regulations will admit of.

To render the work of still greater utility, Seventeen whole-page Illustrations, in addition to the Woodcuts, have been introduced; while every effort has been made that, as the only one of the kind, it should be thoroughly practical and trustworthy.

It may also be proper to state that, except where it had become necessary, the original text of the work has undergone no alteration; which circumstance will account for there being several passages in which the author, in giving the results of his own observation, has employed the personal pronoun.

I desire, in conclusion, to tender my acknowledgments to Dr. Letheby and Mr. F. J. Evans, for their ready aid in furnishing me with many of the facts embodied in the work.

WILLIAM T. SUGG.

VINCENT WORKS,
VINCENT STREET, WESTMINSTER, S.W.,
April, 1867.

INTRODUCTION.

In every large gasworks it now seems to be admitted that the apparatus is not complete without a small experimental retort and suitable appendages, for the purpose of analysing any sample of coal, the value of which, as a gas-producing material, the manager may wish to know. In order, therefore, to assist those who have not given this important subject the attention it deserves, I now most respectfully submit to the profession the following description and method of proceeding with experimental apparatus, and other instruments for the analysis of coal, so as to enable every engineer to determine practically, the value of any kind of coal submitted to him. In doing so, I am far from pretending to say that the methods here given will satisfy all the requirements of analytical gas chemistry, but that they are intended only to meet the wants of practical gas makers, and enable them to determine for themselves, by actual experiment, the quantity of gas and coke produced from a ton of coals, the approximate amount of sulphur and ammonia, the hydro-carbon vapours condensable by bromine, the quantity of carbonic acid and carbonic oxide gases, as well as the carburetted hydrogen contained in a given volume of gas, and lastly, to determine the illuminating power of the gas, which is, after all, the most important commercial test to which it can be submitted.

Instead of describing, separately, each individual instrument, I have thought it better to do so by going through the general analysis of a coal, in the several steps of the process by which the construction and uses of each part of the apparatus will be exemplified.

There are many sources from which illuminating gas may be obtained, but the principal and, indeed, only substances in general demand in this country at the present time are bituminous and Cannel coal. Peat and bituminous shale are sometimes used; but the method of analysis in all cases is nearly the same as that to which our attention is here more particularly to be directed.

The following is the order in which I propose to conduct the analysis of a coal, viz. :—

To ascertain its specific gravity.

The quantity of gas it is capable of producing per ton reduced to the standard temperature and pressure.

The per centage { of hydro-carbon vapours condensible by bromine.
„ of carbonic oxide.
” { of sulphuretted hydrogen present in the foul gas.
„ of carbonic acid ditto.

The specific gravity of the hydro-carbon vapours condensed by bromine.

The specific gravity of the purified gas.

The weight, in pounds, of the gas produced from a ton of coal.

The quantity of ammonia and sulphur compounds which may be present in the purified gas.

The illuminating power.

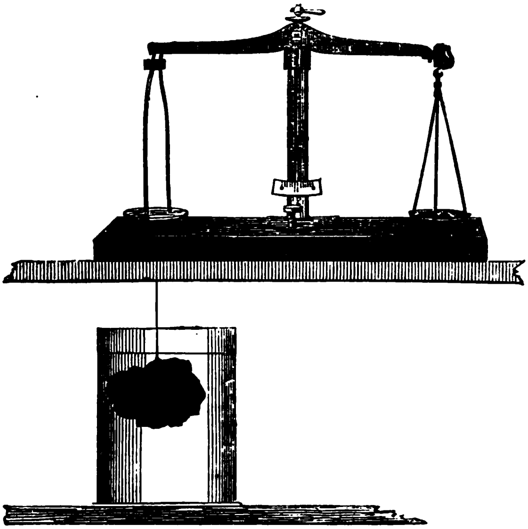
The quantity and value of the ammoniacal liquor and tar.

The quantity and quality of the coke.

Too much care cannot be taken in selecting a fair sample of the coal to be tried; it should be clean and dry, for nothing is so much calculated to deceive an amateur analyst as the presence of moisture in the coal; and, in making a table for his own use, which every gas engineer should do, of the constituents of the various kinds of gas coal, he would be misleading himself if he did not take care that every sample of coal analysed was in the same comparatively dry state,—that is, the coals should be commercially dry.

SPECIFIC GRAVITY OF COAL.

Having chosen a fair sample of the coal, the first thing to be done is to determine its specific gravity by proceeding as follows:—Take a conveniently-shaped piece of coal, and, having carefully adjusted the balance, suspend the coal by a horse hair, or a single strand of silk, to the under side of the pan. Having thus ascertained its weight in air, which I will suppose to be 500 grains, immerse the coal in a vessel of distilled water, and add as many grains to the pan from which the piece of coal is suspended as will just restore the balance to zero. Assume the weight to be 410 grains, then the original weight of 500 grains divided by this weight of 410 grains gives the specific gravity of the coal, which in this case would be 1·219, water being assumed as 1·000. The weight of 410 grains represents the weight of a bulk of water equal to that of the coal.



To prevent any misunderstanding, the above example is worked out in figures as follows:—

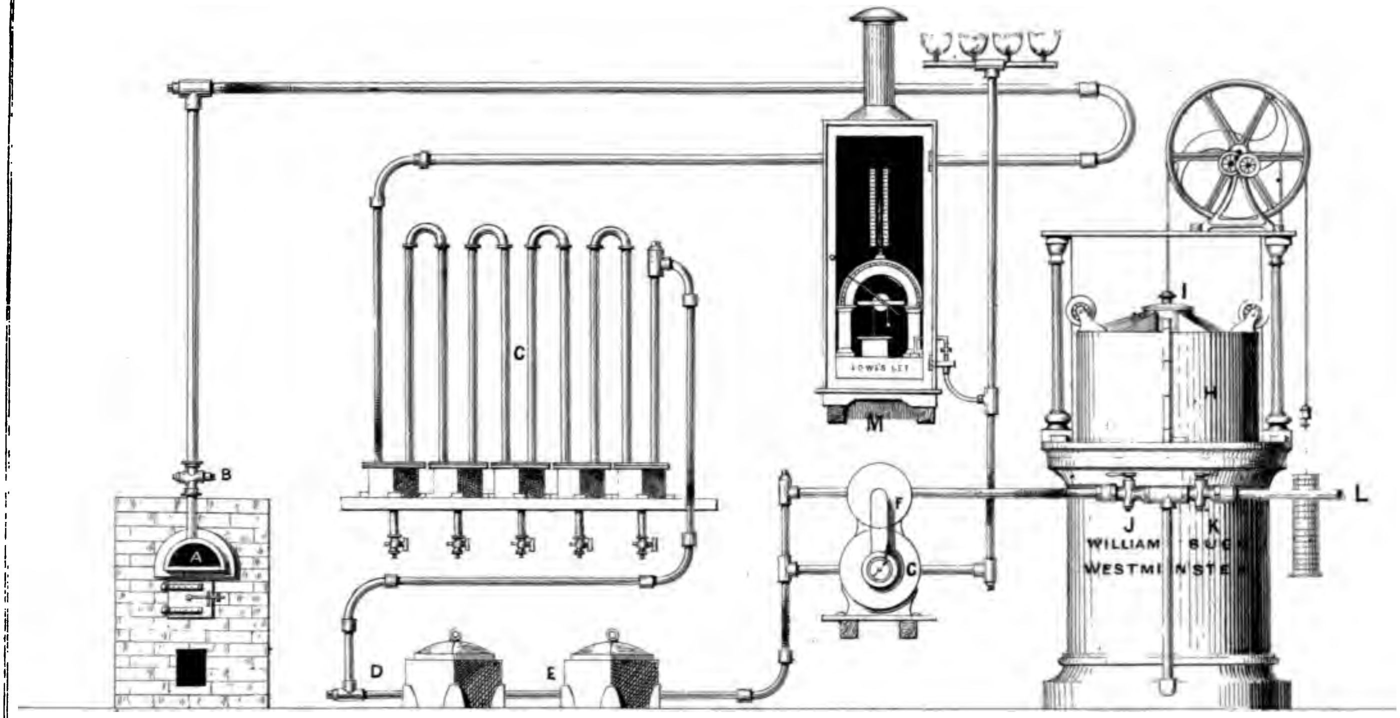
The number of grains required to restore the balance when the coal is immersed in water.		The weight of the coal when weighed in air.		
410	)	500	(	1·219 specific gravity of the coal.
		410		
		.900		
		820		
		.800		
		410		
		3,900		
		3,690		
		. 210		

Or, supposing the sample, before being immersed, weighed 506 grains, and that it requires the addition of 398 grains to restore the balance when weighed in water, then the 506 divided by 398 works out thus:—

Grains.		Grains.		
398	)	506	(	1·271 specific gravity of the sample.
		398		
		1,080		
		796		
		2,840		
		2,786		
		. .540		
		398		
		142		

The foregoing wood-cut illustrates the position of the apparatus when in use, and consists of an ordinary balance, which should be raised upon a stand sufficiently high to admit of a glass jar, to contain water, being placed beneath, and in which the coal is to be immersed. The stand to which the balance is fixed, as also that

EXPERIMENTAL GAS APPARATUS



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upon which it rests, have holes cut through them to allow of the hair or silk by which the coal is suspended being passed and attached to the scale pan.

APPARATUS USED FOR DISTILLATION, &c.

The next operation is the distillation of the coal by means of the apparatus shown in Plate 1, of which the following is a description:—

(A) is the retort of a D shape, 18 inches long from the mouth-piece to the back, 5 inches in diameter, and 5 inches high. This retort is made of cast-iron, $\frac{5}{8}$ths of an inch thick, and capable of taking at a charge 2·24 lbs. of coal, or the $\frac{1}{1000}$th part of a ton. The heat from the furnace, which is fired with coke, passes along the bottom of the retort, which is exposed to its direct action through openings at the end, back again along the sides towards the mouth-piece, and lastly, along the top to the chimney.

In the setting of the retort, I prefer to construct the oven entirely of fire-bricks; but as in some establishments this method might not be convenient, an iron casing, lined with fire-brick, may be adopted, by which means both convenience of form and durability are secured.

The mouthpiece of the retort has a rising pipe attached, which is continued, as shown in the plate, and should not be less than 20 feet in length. At the point (B) a stop-cock is introduced, or the pipe just mentioned may be turned down with a bend into a dip-box, and sealed with water, as in the ordinary hydraulic main; the use of these contrivances will be seen hereafter.

The condenser (C) is of the ordinary form, and consists of 1-inch wrought-iron pipes, of an aggregate length of about 80 feet, arranged vertically, and attached to a number of separate boxes, communicating with each other only by means of the perpendicular pipes. Each of these boxes is provided with a brass stop-cock, so that after the whole of the gas has passed over from the retort to the gas-holder, on opening these stop-cocks, all the tar, liquor, or other condensable products, may be run into a vessel to receive them, and by this means the exact quantities of these constituents of the coal under examination are ascertained.

The two purifiers (D and E) are square in form, and made of cast-iron, and provided with a water joint, and covers, also of cast-iron, sufficiently heavy to retain their proper position without other assistance. They are each fitted with a wooden sieve, and are of such capacity as to contain in each vessel sufficient materials to purify the whole of the gas in one charge of coals. They are, of course, adapted to receive lime, oxide of iron, or any other material the experimentalist may wish to use as a purifying agent. Should the operator be desirous of analysing the foul gas, he will find provision is made between the condenser and purifiers for taking off any quantity he may desire. The apparatus is also furnished with the necessary connections, and a bye pass-cock, so that foul or unpurified gas may pass into the gas-holder, should the experiment require it.

In experimenting upon ordinary coal with the $\frac{1}{1000}$th part of a ton to a charge, a 10-feet gas-holder will in general be large enough; but if cannel is the material operated upon, then one of greater size must be employed, otherwise the whole of the gas even from a single charge cannot be measured, unless some additional contrivance be used. To obviate the inconvenience attending the use of so large a gas-holder, a peculiar form of meter has been devised by Mr. Mann, the Engineer of the City of London Gas Works, by means of which a 10-feet gas-holder may be made to answer the purpose of one of much larger capacity. This will be understood by reference to the plate and the following description.

Two meters (F and G), of equal size, are fixed one on the top of the other. The drum shaft of each is connected in such a manner that one drum cannot revolve without the other. At the back, the inlets to both meters are connected to the same pipe. The outlet from the upper meter is conducted to a float of four or more lights, while the outlet from the lower meter is led directly to the gas-holder. The capacity of the meters being equal, it is obvious that one-half of the gas passing from the retort will be led away to the float, and there consumed, while the other half goes forward to the gas-holder, and is there stored for further experiment. This arrangement has also the advantage, that the portion stored is an exact half of the whole make, both in quantity and quality.

Similar meters, bearing different proportions to each other, to those just described, are constructed to suit the particular views and requirements of individual operators, and may be obtained from the makers.

Upon inspecting the lower meter, which is provided with an index, the quantity of gas passed can be readily ascertained. This amount doubled, or the same quantity added to that contained in the gas-holder, gives the total number of cubic feet produced.

This meter is by no means an indispensable requisite; it is merely designed to remedy the inconvenience of too large a gas-holder, or where space or expense is a consideration.

The gas-holder (H) is an ordinary 10-feet gas-holder, such as is used for testing meters, made of tin plate, and working in a cast-iron tank. It is furnished with a cycloid and counterbalance weights, so that during the carbonization of the coal, and the consequent passage of gas to the holder, by a proper adjustment of the weights, all unnecessary pressure may be taken off the retort. The scale attached to the gas-holder is so divided, that it shows at once, by inspection, the quantity of gas produced. In use, it is necessary that the tank should have sufficient water in it just to cover the crown of the gas-holder, so as to ensure that the whole contents of the holder are displaced by the water. There will, however, be a few square inches left in the small chamber (I), into which the inlet-pipe rises, but the space is so small, and the quantity of air it contains is so insignificant, that it can scarcely be said to affect the experiment. There is but one pipe within the gas-holder which serves both as inlet and outlet, the direction of the gas being determined by the opening and closing of the cocks (J, K) at the side of the gas-holder.

The pipe (L), when in use, is connected with the photometer, to determine the illuminating power, or with such other apparatus as the nature of the experiment may dictate.*

DISTILLATION OF COAL.

Having heated the retort to the proper temperature, open all the cocks and fill the gas-holder tank with clean water to such a height as will just cover the crown of the gas-holder, so that when it is slightly raised from the bottom of the tank the surface of the water and the edge of the crown may be exactly even; the index will then point to zero. If a meter is employed, see also that it is supplied with water and adjusted to the proper line.

---

* A jet photometer (M) may be connected, as shown in the drawing, to the outlet-pipe of the waste meter (G), where it will be very useful in showing the variations in the illuminating power of the gas from different portions of the charge.

Next, charge each purifier with the material intended to be used as a purifying agent, which should be sufficient to purify the gas produced from the coal about to be carbonized. The object of having two purifiers is to admit of the use of two different kinds of material, for instance, oxide of iron in the first, and lime in the second, or some other of the various materials employed for purification. Another reason for having this part of the apparatus in duplicate is to enable the operator to ascertain whether the gas made from the particular coal under examination requires more purification than in general. It is, however, desirable to make a separate experiment, with this sole object in view, whenever suspicion warrants it. For this purpose the first purifier should be charged with a quantity of material only very slightly in excess of what is sufficient to purify the gas produced from the coal. The second should also be partially filled with an indefinite quantity of the same material, which, while it ensures the thorough purification of the gas before it enters the gasholder, also indicates whether the material in the first one has done its duty, if not, then the inference is that the gas is unusually foul, or the material too inert; so that if we find upon examination that the material in the second purifier has become fouled, we may conclude that, in practice, gas made from such coal will entail more than the average expense for purification, supposing the same purifying material to be used. Of course these remarks apply equally to lime, oxide or other material.

Then, having procured a fair sample of the coal, take about 1 cwt., pound it, and pass it through a coarse sieve. From this mass weigh 2·24 lbs. and place them in the scoop. All the cocks, excepting those which interfere with the direct passage of the gas from the retort to the condenser, purifiers, and gas-holder, are now to be closed. The scoop with its contents should then be placed in the retort, the lid of which, previously luted with clay or lime, being at once secured as quickly as possible. I would here remark, that it is necessary some care should be bestowed in preparing the luting so as to free it from any stones or lumps which would prevent the lid from fitting closely and making a tight joint. Though the method of leaving the scoop in the retort possesses advantages that render it in most cases to be preferred, yet the ordinary one in which the scoop is withdrawn can be adopted if desired.

Immediately after the lid has been secured, a sufficient number of counter-balance weights should be added to the gas-holder, so as to take off all pressure upon the retort, or so as to produce "a level gauge."

When the charge is worked off, which will be seen when the gas-holder ceases to rise, shut off the inlet cock (J), and note the quantity of gas contained in the holder, which will be shown by the scale attached. The small brass cocks at the bottom of the condenser should then be opened, and the tar and liquor permitted to escape into the receptacle appointed for them. These products should be measured and the quantities noted. The lid may now be removed from the retort, and having carefully drawn the whole of the coke and allowed it to cool in the open air, weigh it, and put it on one side for further examination.

Considering the smallness of the quantity of coal operated upon, viz., 2·24 lbs., and that the whole of the pipes, condensers, and purifiers, are, at starting, filled with air, which would become mixed with the gas to its prejudice, the result of the first charge would not give, unless preventive measures were adopted, a fair indication of the illuminating power of the gas. It is therefore suggested, that the retort should be charged with half the usual quantity of coal, and the gas allowed to blow through, and drive out the air contained in the apparatus, before proceeding with the complete experiment. It is, however, preferable (after allowing the products from the first half charge to escape) to make three distinct experiments, which if carefully conducted upon the same kind of coal, and the average taken, a very close approximation to accuracy may be fairly relied upon.

As the operator may in the course of his investigation wish to analyse the foul gas, provision is made between the condenser and purifiers for taking off samples. If, however, it is imperative that it should be collected in the gasholder, then it cannot be too forcibly impressed upon him the necessity for thoroughly cleansing the whole of the apparatus beyond the condenser, before again using it, as the want of this precaution will most materially affect the purity of the gas in the next experiment. In all cases after foul gas has been allowed to pass through a vessel containing water, it is of the utmost importance that the water should be drawn off, and replaced with clean, before proceeding afresh.

CORRECTION OF BULK FOR TEMPERATURE AND PRESSURE.

In consequence of the extreme facility with which aeriform bodies are affected by variations in the temperature and pressure, these must always be taken into account when speaking of their volumes. It has therefore been customary to reduce them to what is called mean temperature and pressure, the mean temperature being 60 degrees Fahrenheit, and the mean pressure sufficient to balance 30 inches of mercury. This is the most convenient standard, and the one usually adopted, although, by Act of Parliament, the temperature at which the specific gravity of spirits is determined, and weights and measures adjusted, is 62 degrees.

First as to pressure :—the bulk of a given quantity of gas, or any aeriform body, increases or decreases inversely as the pressure. Suppose, for instance, it is required to know what volume 1,000 cubic feet of gas at 29 inches barometrical pressure would occupy at 30 inches, then—

	Standard pressure in inches.		Cubic feet.		Actual pressure in inches.
As	30	:	1,000	: :	29
			29		

30)29,000(966$\frac{2}{3}$ *Answer.*
270
.200
180
.200
180

$\frac{20}{30} = \frac{2}{3}$

that is to say, 1,000 cubic feet at 29 inches pressure, would be reduced to 966⅔ feet at 30 inches.

Next, as to temperature: Dalton and Gay Lussac ascertained that 1,000 feet of air, when raised from 32° to 212°, expanded 375 feet; so that 1,000 feet at 32° occupied 1,375 at 212°; that is, an increase of temperature of 180° (the difference between 212° and 32°) increased the volume 375 feet, or 2·083 feet for every degree. If now 1,000 be divided by 2·083, the quotient will be 480, from which it appears that gas expands $\frac{1}{480}$th of the volume it occupied at 32° for every increase of one degree of heat. Suppose, for example, we require to know what volume 1,000 feet at 70° would occupy at 60°, we must bear in mind that it is not $\frac{1}{480}$th part per degree of the observed volume at 70° which is to be deducted, but $\frac{1}{480}$th part of the volume which 1,000 feet at 70° would occupy at 32°. Now, 480 parts at 32° become 481 at 33°, and increase one part for every degree; so that at 60° it would become 480+28=508 parts, and at 70°, 480+38=518 parts; then by the following proportion, we obtain the required volume:—

As 518 : 1,000 : : 508
508

518)508,000(980·7 *nearly.*
4,662

.4,180
4,144

.3,600

980·7 cubic feet then is the volume which 1,000 feet at 70° would occupy if the temperature were reduced to 60°. The foregoing rule is popularly expressed in the following manner:—480 plus the difference between 32° and the observed temperature, is to 480 plus the difference between 32° and the standard temperature, as the observed volume of the gas is to the required volume of the gas.

The late Mr. Alexander Wright, of Millbank Street, Westminster, has published a table with his specific gravity apparatus, which is exceedingly useful in reducing the volume of a gas to the standard temperature and pressure. This table is inserted in his

Analysis of Gas for Practical Men, and I would advise those of my readers to purchase it who do not wish to go through the calculations explained above.

Next proceed to examine the purified gas in the gas-holder, and the sooner this is done the better, for as the gas in it is exposed to a surface of water twenty or thirty times greater than is the case with that manufactured for commercial purposes, if suffered to remain too long, an immoderately large proportion of the hydrocarbon vapour and ammonia will be absorbed.

ANALYSIS BY THE EUDIOMETER TUBE.

The eudiometer is an instrument used for measuring small quantities of gas, and consists of a long glass tube, closed at one end and open at the other (Pl. 2). The closed end is sometimes swelled out into a hollow ball or cylinder, as shown at (A) or (B), or it may be made uniform in diameter throughout, as at (C) or (D). The stem is graduated, and in all cases the open end is curved, as shown in the various illustrations. Whatever the form of the instrument, whether that of A, B, C, D, or E, the manipulation is the same. The mode of procedure to determine the constituents of the gas, is as follows:—

Remove a sufficient number of weights from the counterbalance so as to give about an inch pressure on the gas-holder, and to the outlet pipe of which attach a piece of india-rubber tube about $\frac{1}{8}$th inch diameter. It is usually the custom to fill the eudiometer with water, and then to pass into it the small india-rubber tube, and thus fill the instrument with gas by the displacement of the water; but, in consequence of the rapid absorption of the hydrocarbons, ammonia, and carbonic acid, by water, I consider it much better to pass the flexible tube quite into the bulb of the eudiometer when filled only with atmospheric air, and to let the gas blow off for some seconds, so as to displace the whole of the air, and then to withdraw the india-rubber pipe under water. It is generally advisable to fill the tube about one division below zero, so as to allow for its condensation. When thus filled with gas, place the eudiometer in the condenser (F), which is a vessel made of tin plate to contain water, and is sufficiently deep to

[illegible], and I would advise those of my readers [illegible] not wish to go through the calculations [illegible].

[illegible] the purified gas in the gas-holder, and [illegible] is exposed to [illegible] than is the case [illegible] common purposes, it suffices to [illegible] proportion of the Hydro- [illegible]

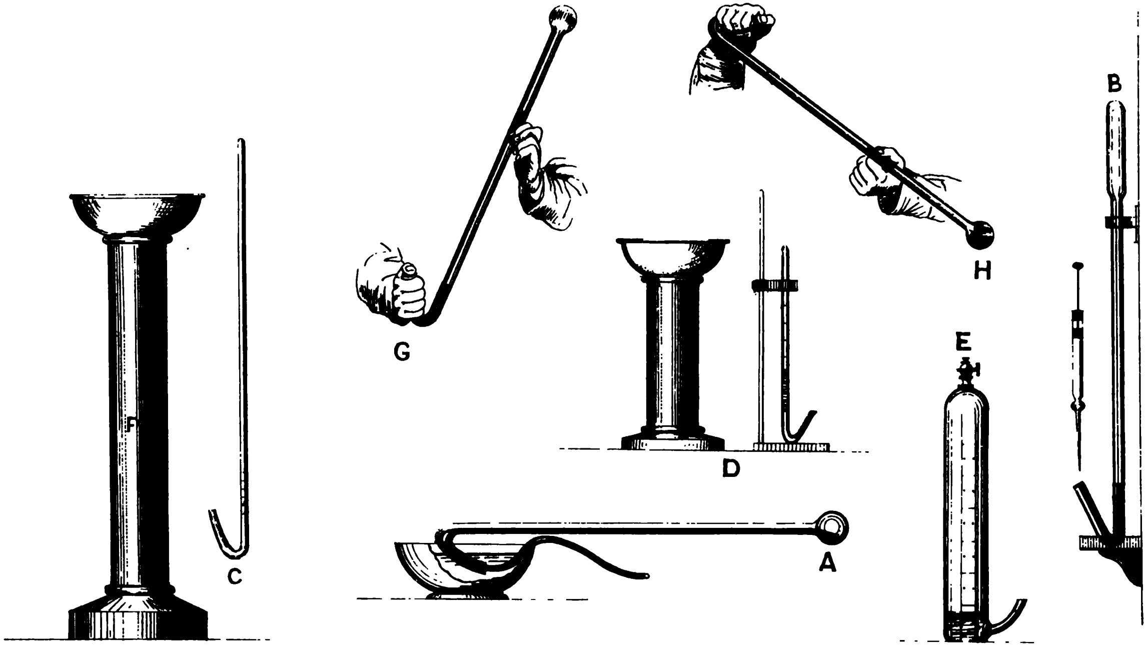
[illegible] WATER TUBE.

[illegible] small [illegible] and [illegible] at it, or [illegible] is [illegible] the [illegible]

[illegible]

[illegible] to

ANALYSIS BY THE EUDIOMETER



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admit of the eudiometer being completely immersed in the liquid. The effect of this operation is to cool the gas, and upon removing it, attention must be directed to see that the gas is exactly at the zero point of the eudiometer, if not, some more gas must be added or let out, as the case may be. Some bromine water should be previously prepared, by adding 20 to 30 drops of pure bromine to 1 ounce of distilled water, and allowing them to stand for 24 hours, or till well incorporated. Now place the eudiometer in an upright position, as at B, and by means of a glass syringe, inject from half-an-ounce to an ounce of the bromine water, taking care to *completely* fill the curved end of the instrument. Then cover the open end of the tube with the thumb, in the manner shown in the plate, at C & H, and well agitate, allowing the bromine and water to pass freely from one end to the other; slight red fumes will rise, which is the vapour of bromine, and these combine with the hydro-carbon vapours, the principle light-giving constituents of the gas. Bring the water into contact with the thumb again; this should be done very gradually and carefully, so as to allow the whole of the gas to return to the straight part of the tube; if done suddenly it will be almost certain to leave a portion of gas in the short leg, which, when again submitted to the condenser and the thumb withdrawn, will escape in the form of a bubble. The consequence would be, that a greater condensation would be indicated by the scale than had actually taken place. Particular attention having been paid to this part of the operation, place the hand containing the tube under water, remove the thumb, and let the eudiometer remain immersed for ten minutes to give time for the more effectual combination of the bromine with the hydro-carbons. Upon removing the instrument, a small quantity—say half-an-ounce to an ounce—of solution of caustic potash is to be added, and the tube agitated as before; this will condense the excess of bromine. The tube is then to be returned to the condenser. The liquid in the eudiometer containing bromine and potash, is of much higher specific gravity than water, it will therefore fall rapidly, and its place will as rapidly be taken by the clear liquid in which the tube is immersed. When this action has ceased, the eudiometer is to be withdrawn from the condenser sufficiently high to admit of the amount of condensation being read off from the scale attached, and this reading shows the per centage of hydro-carbon vapours condensable by bromine, which varies greatly with the gas produced from different kinds of coal.

To determine the quantity of carbonic acid in the gas, the operation of filling and placing in the condenser, &c., should be gone through as directed before, but instead of using bromine, some solution of caustic potash is to be applied, the tube well shaken, and the condensation read off as in the previous experiment.

The quantity of the different solutions directed to be employed will, of course, vary with the size of the instrument, but it will be a safe rule to apply about sufficient to fill the short leg of the tube.

To ascertain how much carbonic oxide there is, the tube should be refilled with gas, as before, and a solution of the proto-chloride of copper, acidified with muriatic acid, should be added; agitate again, remove the thumb under water, and place the eudiometer in the condenser. Upon its removal, read off from the scale the percentage of carbonic oxide.

The above method of analysis will apply equally to purified or unpurified gas; but with foul gas, before going through the processes referred to above, the following means must be adopted, in order to ascertain the percentage of carbonic acid and sulphuretted hydrogen.

The tube is to be filled with foul gas, and placed in the cistern in precisely the same way as for clean gas; but instead of adding bromine, the first test will be for ammonia. This is done by applying a small quantity of dilute sulphuric acid, specific gravity about 1068·2 (water=1,000); the resulting condensation will show the percentage. Then add a weak solution of sulphate of copper, which will condense the sulphuretted hydrogen. Again note the amount of condensation which ensues. A few drops of solution of caustic potash is now to be mixed, which will determine the quantity of carbonic acid; after which proceed as directed for clean gas. The whole of these experiments should be gone through three times, and the average taken, in order to ensure accuracy in the results.

In speaking of the condensation of the hydro-carbon vapours in coal gas by means of bromine and other agents, I ought not to omit to mention that there is a substance which will effect this object quite as successfully as bromine, and it is one which, at first sight, we should hardly expect to have this peculiar property. In the winter of 1860–1861, Mr. F. J. Evans caused a naphtha box to be put up at the gas-works in Horseferry Road, for the purpose of improving the illuminating power of coal gas, when it was found that the photogenic power of the gas was very much decreased after passing through the naphtha, a circumstance which was at once attributed to the low state of the temperature, the thermometer at the time being below the freezing point; and, upon using naphtha instead of water in the eudiometer, it was found that the condensation was precisely the same as with bromine. Now, although it is quite clear that the naphthalising of gas depends partly on temperature, and partly on the mere mechanical effect produced by the gas passing over or through the naphtha; yet the condensation of the hydro-carbon vapours by this means does not seem to depend upon temperature at all, for, having made a great many experiments with the intention of setting this question at rest, I have invariably found that at temperatures ranging from 28° to 60° Fahrenheit, the condensation by naphtha has been identical with that by bromine, when the specific gravity of the naphtha was above ·800.

The same result may be produced by using turpentine, olive oil, or, in fact, any oleaginous body. Coal-tar, or pitch granulated with sawdust or fine sand, also effects it—the gas being allowed to pass through, it is deprived of its hydro-carbon easily, and also of the bi-sulphuret of carbon.

It may be as well, perhaps, in this place to remark, that the specific gravity of the hydro-carbon vapours condensable by bromine varies very much with the different kinds of bituminous and Cannel coals. Mr. Lewis Thompson states, in his treatise on the Chemistry of Gas Lighting, published in vols. 2 & 3 of the *Journal of Gas Lighting*, that the specific gravity of the light-giving matter in Newcastle coal gas ranges from 2·80 to 3·3; and, in the table annexed, it will be seen that, in the Cannel coals, it ranges from 1·21 to 2·28.

The following results were obtained by Mr. F. J. Evans, at the Westminster station, and in each case three distinct experiments were made:—

Name of Cannel.	Gas per Ton.	Condensation per cent. by Bromine.	Specific Gravity of Gas.	Specific Gravity of condensed matter.	Photogenic Power, Candles.	
					Actual.	By Analysis.
Boghead	15,000	30·	·752	1·21	37·75	36·30
Lesmahagow, No. 1	13,500	16·	·642	1·64	27·10	26·24
Lesmahagow, No. 2	13,200	17·	·618	1·43	24·80	24·31
Capeldræ	14,400	16·5	·577	1·29	19·75	21·28
Arniston	12,600	17·0	·626	1·40	22·50	23·80
Ramsay	10,300	12·5	·548	1·82	21·40	22·95
Wemyss	14,300	14·5	·580	1·87	24·50	27·11
Kirkness	12,800	10·2	·562	1·95	21·20	19·88
Knightswood	13,200	9·5	·550	2·28	19·00	21·66
Ince Hall	11,400	11·5	·528	1·77	20·00	20·35

From an inspection of this table, it will be at once perceived that the amount of condensation by bromine multiplied by the specific gravity of the condensed matter, gives the photogenic power by calculation, which corresponds very nearly with the actual results obtained in the photometer.

The following table, for which I am also indebted to Mr. F. J. Evans, shows the yield of bituminous coal, and illuminating power of the gas:—

Name of Coal.	Gas per ton.	Illuminating Power, Candles.	Specific Gravity of Gas.	Condensation by Bromine.
Pelton	11,000	14·0	·430	4·5
Do. Cannel	11,500	18·5	·520	10·5
Leverson	10,800	12·5	·425	4·0
Do. Cannel	11,600	18·0	·523	10·0
Washington	10,000	14·0	·430	5·0
Do. Cannel	10,500	18·08	·500	10·5
Pelaw	11,000	12·75	·420	4·5
New Pelton	10,500	12·00	·415	4·75
Dean's Primrose	10,500	13·5	·430	5·0
Garesfield	10,500	11·5	·398	3·75
Gasforth	10,000	12·0	·402	4·0
West Hartley	10,500	12·5	·420	4·2
Hastings' Hartley	10,300	12·5	·421	4·3
Blenkinsopp	9,700	14·0	·450	6·0

SPECIFIC GRAVITY OF THE VAPOUR CONDENSED BY BROMINE.

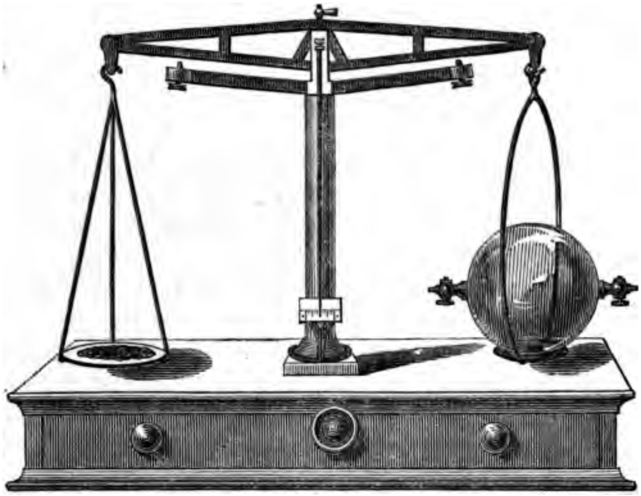
Before proceeding further, I shall describe, as shortly as I can, the method adopted by Mr. Lewis Thompson for ascertaining the specific gravity of the vapour condensed by bromine. The specific gravity of the gas must be first carefully ascertained in the way hereafter to be described. Let us suppose it to be ·752. A large glass vessel (E), plate 2, about 18 inches high and 4 inches in diameter, is provided with a well ground stop-cock at the top and a curved pipe at the bottom, similar to the open end of the eudiometers before described. This vessel is divided into 100 parts, and has a scale engraved upon it. Having filled it with water, close the stop-cock and introduce the gas through the open-ended curved pipe; allow the gas to pass into the vessel until the water line is brought down to zero; place the eudiometer tube in the condenser; put in a sufficient quantity of the bromine water, agitate, condense, in fact, operate exactly as when using the ordinary eudiometer tube, and then carefully note the scale. Suppose the condensation has been, as in the case of Boghead cannel gas, in the above table, 30 per cent.; the next process will be to ascertain the specific gravity of the gas remaining in the vessel. For this purpose a glass ball is provided, having a ground stop-cock, which at the lower part is formed into a plug in lieu of a screw, and fits closely into the neck of the stop-cock on the top of the vessel. Having balanced the ball in a delicate balance, exhaust the air out of it by means of an air pump, and then weigh again; the number of grains required to bring the balance into equilibrium represents the weight of the air abstracted. Now attach the ball to the vessel by means of the two stop-cocks, and having immersed the vessel in water, open the cocks gently, and the ball will be immediately filled with gas. Weigh again accurately, and the number of grains will represent the exact weight of the gas introduced into the ball. Then the weight of air abstracted is to the weight of gas introduced as unity is to the specific gravity of the gas, which in the case above referred to was ·555—the average of three experiments.

We now have the following results:—

Original specific gravity of gas ·752; or,
Specific gravity of 100 volumes ·752
Ditto 70 do. ·555
then 100 × ·752 = 75·2
70 × ·555 = 38·90

Specific gravity of remaining 30 parts 36·30 and 36·30 divided by 30=1·21, the specific gravity of the matter condensed by bromine.

SPECIFIC GRAVITY OF GAS.



I will now proceed to describe the two processes most usually employed for determining the specific gravity of a gas; and first by means of a glass globe. To carry out this experiment accurately, a good air-pump is absolutely necessary; a very light globe, made of hard German glass, is provided, with a stop-cock at each end. The capacity of this ball is about 100 cubic inches. Having adjusted the balance, weigh the globe accurately to the fractional part of a grain, and then remove it to the air-pump; exhaust the air, weigh it again, and the number of grains and tenths of a grain represent the weight of the air abstracted. Suppose it takes thirty-one; now fill the ball with gas from the gas-holder. Remove it, and weigh it again, and the number of grains represents the weight of the gas introduced. Suppose it takes thirteen; then—

As 31 : 13 :: 1·000
13

31) 13·000 (·419 *Answer.*
124
. . 60
31
290
279
. 11

The specific gravity of the gas is therefore ·419, air being taken at 1·000; and as 100 cubic inches of pure and dry atmospheric air weigh at mean temperature and pressure 31·0117 grains, the weight of 100 inches of the gas can be easily determined; for,

As 1·000 : ·419 :: 31·0117
·419

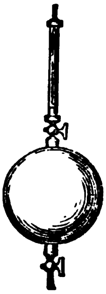
2791053
310117
1240468

1·(000) 12·9939(023

12·9939 *Answer.*

that is, as the specific gravity of air is to the specific gravity of the gas, so is the weight of 100 inches of air to the weight of 100 inches of the gas, and from this result the weight of any quantity of the gas can of course be determined.

Dr. Letheby's method of ascertaining the specific gravity of gas is as follows:—He uses a glass globe, of about 6 inches in diameter, with a double neck. The two necks are opposite each other, and are fitted with small caps and very small stop-cocks. One of the stop-cocks screws into a gas-pillar, and so supports the globe; the other carries a cap, with a glass tube about ½ an inch in diameter and 7 inches long. This tube contains a thermometer, and is fitted at the opposite end with a jet for burning the gas.



The globe with the stop-cocks attached, but without the tube, is accurately balanced while in an exhausted state, and a counterpoise weight is provided. The exact weight of the globe when full of air at 60° Fahrenheit, and 30 inches barometrical pressure is ascertained, and engraved on the globe.

In practice, the globe is always attached to the gas-pillar, and therefore gas is constantly passing through it, so that it is always full of gas ready for weighing. When the specific gravity is required, the gas is shut off by first turning the *lower* stop-cock, and then, a moment after, the upper one, so that the globe at the time of weighing has not the contained gas at the pressure in the main, but at the atmospheric pressure. It is then suspended from the beam of the balance, and its exact weight determined. By a simple rule of three, the specific gravity of the gas is ascertained. For instance, say the weight of the globe, when full of air, is 60 grains more than the counterpoise of the globe in its exhausted state, and that when taken from the gas-pillar, and is full of gas, the weight of the globe is 25 grains; then, as 60 : 1·000 (the specific gravity of air) : : 25 : 416 (the specific gravity of the gas). This example is worked out thus—

Weight of globe, when full of air, in grains.		Standard specific gravity of air.		Weight of globe, in grains, when filled with gas.
60	:	1·000	: :	25
				1·000
			6,0)	25·00,0
				.416 *Answer.*

Correction is then made for temperature and barometric pressure, in the manner described under that head (page 10).

The advantage of this apparatus is, that it requires no exhausting by an air pump, but is always ready for experiment. To operate successfully, however, with either form of apparatus described, access to a very delicate balance is indispensable.

CORRECTIONS FOR MOISTURE.

It is sometimes necessary, in making very delicate experiments on coal gas, to allow for moisture or aqueous vapour present, for it is a well-established fact that gas absorbs a certain quantity of aqueous vapour, proportional to the temperature when standing in the gas-holder in contact with water. Suppose a gas, for instance, to be saturated with moisture from the above cause, its weight, and therefore the determination of its specific gravity, would be affected to a certain extent by the quantity of moisture present, the vapour of water being much lighter than the gas. The weight of the moist gas must, therefore, be first ascertained in the manner described above; from this the weight of the known volume of aqueous vapour must be abstracted, and the remainder will represent the weight of the dry gas.

The following table, which is founded upon the experiments of Dalton and Ure, exhibits the proportions by volume of aqueous vapour existing in any gas standing in contact with water at the corresponding temperatures, and at mean barometric pressure:—

Degrees.	Volume of Aqueous Vapour.	Degrees.	Volume of Aqueous Vapour.	Degrees.	Volume of Aqueous Vapour.
40	·00933	54	·01533	68	·02406
41	·00973	55	·01586	69	·02483
42	·01013	56	·01640	70	·02566
43	·01053	57	·01693	71	·02653
44	·01093	58	·01753	72	·02740
45	·01133	59	·01810	73	·02830
46	·01173	60	·01866	74	·02923
47	·01213	61	·01923	75	·03020
48	·01253	62	·01980	76	·03120
49	·01293	63	·02050	77	·03220
50	·01333	64	·02120	78	·03323
51	·01380	65	·02190	79	·03423
52	·01426	66	·02260	80	·03533
53	·01480	67	·02330		

In using this table, which embraces a range of 40° Fahrenheit, opposite the observed temperature of the gas will be found the proportion in volume of aqueous vapour at a pressure of 30 inches. This volume must be corrected to the mean temperature of 60°, and then deducted from the volume of the gas corrected to mean temperature and pressure; the remainder will be the volume of dry gas. For instance: suppose 100 cubic inches of gas weigh, in the glass ball before referred to, 17 grains, the temperature at the time being 70°, and the barometer 30·2 inches, by reference to the table, opposite 70° will be found ·02566, as the portion of vapour present at that temperature, and ·02566 × 100 = 2 566 inches, the total quantity in 100 inches: this must be reduced to the mean temperature, as before explained:—

480 + 38 : 480 + 28 : : 2·566 : 2·516.

Now to ascertain the volume of the gas:—100 inches at 70° will be reduced to 98·069 inches at 60°; for

480 + 38 : 480 + 28 : : 100 : 98·069;

and this amount, corrected for pressure, will become 98·722; for

30 : 30·2 : : 98·069 : 98·722;

and if from 98·722 be deducted 2·516, the remainder, 96·206, will represent the volume of dry gas at mean temperature and pressure. Now, it has been ascertained, with perfect accuracy, that a cubic inch of permanent aqueous vapour, at a temperature of 60° and barometer 30 inches, weighs 0·1929 grains; therefore, 2·516 inches multiplied by ·1929 will équal ·4853, and this subtracted from 17 grains (the whole weight) will leave 16·5147 grains—which will be the weight of 96·206 inches of dry gas; and, by a simple proportion, it will therefore be found that 100 inches of such gas at mean temperature and pressure will weigh 17·165 grains. The best method that can be adopted to dry the gas, is to pass it through a glass tube about 24 inches long and ¾ inch internal diameter, filled with pieces of perfectly dry chloride of calcium, which, by its strong attraction for moisture, rapidly abstracts the whole aqueous vapour present. The gas must not pass through this tube too quickly, about ten minutes being required to operate successfully upon 100 inches of gas. When the chloride is not perfectly dry, it may be fused in a common retort, and used as soon as cold.

AMMONIA

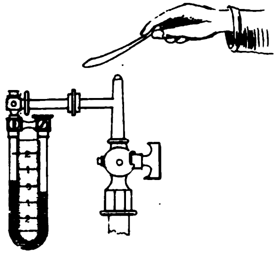


Fig: 1

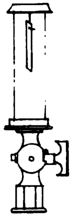


Fig: 2

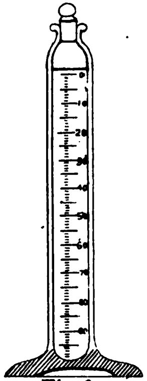


Fig: 9

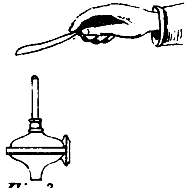


Fig: 3

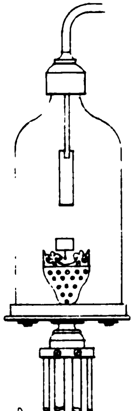


Fig: 4

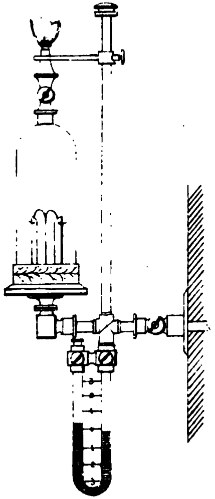


Fig: 5

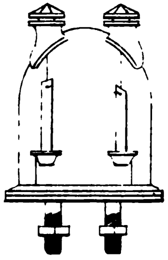


Fig: 6

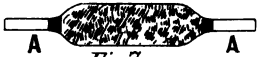


Fig: 7

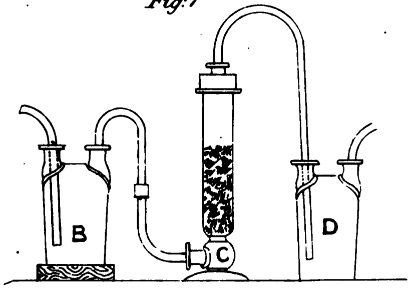


Fig: 14

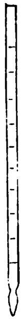


Fig: 8

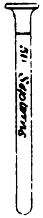


Fig: 12

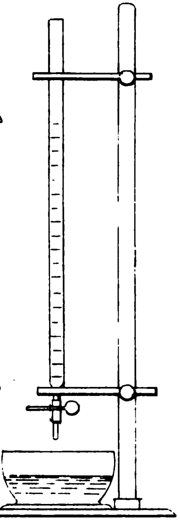


Fig: 15

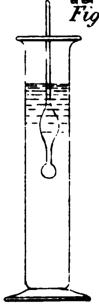


Fig: 11

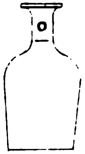


Fig 10

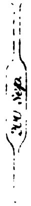


Fig. 16

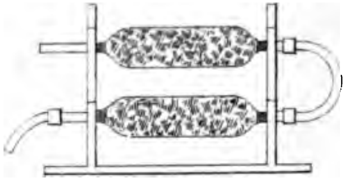


Fig 13

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AMMONIA.

"The Metropolis Gas Act" of 1860 enacts, that the gas supplied to the inhabitants of London

> "shall, with respect to its purity, be so far free from ammonia and sulphuretted
> "hydrogen that it shall not discolour either turmeric paper, or paper imbued
> "with acetate of lead, when these tests are exposed to a current of gas issuing
> "for one minute under a pressure of five-tenths of an inch of water."

In order to detect the presence of ammonia, it is sufficient to allow a jet of gas to blow upon a piece of turmeric or reddened litmus paper, as shown in Pl. 3, Fig. 1. If ammonia be present, the turmeric paper becomes of a red colour, deep or faint, according to the quantity of the alkali contained in the gas; and if reddened litmus paper be applied, it will be changed to blue in a similar manner.

The Act does not specify the rate per hour at which the gas should issue from the orifice over which these tests should be applied; the consequence of this omission, therefore, causes a considerable difference in the results obtained by the various appointed gas testers, owing to the latitude given to individual operators in the application of the test, which, though strictly in accordance with the Act, is not sufficiently definite to admit of fair comparison. It is clear that the greater the quantity of gas, the greater must be the quantity of ammonia; therefore a gas which, issuing from an orifice at the rate of 10 feet per hour, distinctly colours the test-paper, will perhaps not do so at all when discharged at the rate of only 2 feet per hour. This is more particularly evident when the gas to be tested is made to pass through a glass tube (Fig. 2) containing the test-papers.

It is to be regretted that the method adopted by a few of the public experimentalists is not more uniformly employed. Their practice is to apply the test to gas issuing from a burner, regulated by a governor to pass 5 cubic feet per hour (Fig. 3)—the standard quantity for testing the illuminating power. This coincides with the system in use by the French experimentalists, which is to cause the gas to issue from a burner similar to that by which the illuminating power is tested (Fig. 4).

The instrument (Fig. 5) is used by Mr. Hugh Young at the

Saltley station of the Birmingham and Staffordshire Gas Company, both for detecting the presence of ammonia, and as a constant test for sulphuretted hydrogen. It is simply a small porcelain cup, constructed with a mercury seal, in which is placed a glass receiver. The gas enters from the bottom, and passes through the receiver to an exit tube at the top, fitted with a burner, at which the gas is kept burning day and night continuously. Acetate of lead and turmeric papers are suspended over the orifice, by which the gas enters, and show at once by their discoloration the presence of either sulphuretted hydrogen or ammonia.

Fig. 6 is a differently formed instrument for the same purposes, having cups to contain water, and solution of acetate of lead for moistening the test papers which are suspended above them.

The foregoing tests, however, merely show the presence of these impurities, but give little or no indication as to their quantity.

To ascertain the amount of ammonia contained in a given volume of gas, a very different apparatus is requisite, which consists of a meter with dial so arranged as to show any consumption from ·01 up to 1,000 cubic feet; an ammonia tube with bulb, 7½ inches long by 2½ inches diameter, of the form shown in Plate 3, Fig. 7; a graduated pipette to contain 100 grains (Fig. 8); a test mixer to contain two deci-gallons, divided into 100 parts (Fig. 9); a deci-gallon bottle (Fig. 10); an hydrometer (Fig. 11); a graduated tube (Fig. 12), to hold 50 septems to moisten the fragments of glass contained in the ammonia tube; and a Mohr's burette to contain a centi-gallon (Fig. 15).

The experiment can be performed by the aid of either oxalic acid, or sulphuric acid, but, if it is desired to find the quantity of ammonia at the same time, and with the same meter as that employed to determine the amount of sulphur present, then it is preferable to use oxalic acid, in order that the experiment for arresting the sulphur may in nowise be interfered with by any fumes or vapours containing free sulphuric acid, which might be carried forward mechanically combined with the gas. Otherwise it is of no consequence which acid is employed.

The first thing to be done is to prepare a standard solution of sulphuric acid, which is performed in the following manner. Take a quantity of anhydrous carbonate of soda as purchased from a chemist, and put it into a white porcelain cup, or Wedgewood-ware crucible. Place it over the flame from a Bunsen burner till it is red hot; keep it in that state for a few minutes, and then allow it to cool under a glass shade. The effect of this is to drive off any moisture it may contain. From the mass weigh 53 grains, and put them into a deci-gallon measure (Fig. 10), filling the bottle up to the mark on the neck with distilled water, and this solution serves to ascertain the strength of the sulphuric acid solution now to be made.

Take a porcelain or glass dish large enough to hold a pint, and into it pour the deci-gallon of carbonate of soda solution. Rinse the bottle with a little distilled water, and add the washings to the bulk of the liquor in the basin. Add a sufficient quantity of tincture of litmus to colour it distinctly blue.

Make ½ a gallon of a solution of sulphuric acid (with distilled water) of the specific gravity 1,397 (water being 1,000), as determined by an hydrometer (Fig. 11). Measure 100 grains of this solution by means of the pipette (Fig. 8), and drop them gradually into the blue liquor in the basin until the colour of it is changed to pink. During this process the basin should be placed over a Bunsen burner, and its contents kept boiling, in order to expel the carbonic acid contained in the liquid. If, after allowing them to remain boiling a short time, the blue colour of the liquid returns, add a little more acid, sufficient to change it to a neutral tint. Note the total number of fluid grains of acid, as shown by the pipette, which have been dropped into the deci-gallon of soda solution. If the whole 100 grains have been used, then the acid is of the correct strength, and will require no further alteration; but if less, then its strength must be diluted in the following manner:—

Take a two deci-gallon test mixer (Fig. 9), divided into 100 parts, and from the ½ gallon of sulphuric acid solution before spoken of, fill up the mixer to such a height that the number of parts in it shall equal the number of grains dropped from the pipette into the soda solution—thus: suppose the number of grains dropped from the pipette is 98, then the number of parts to be filled up in the test mixer will be 98 also; now add sufficient distilled water to fill the measure up to 100 parts. Empty the mixer into a half-gallon vessel, and re-fill it in the manner just described until the whole quantity of the acid solution be similarly meter and so lost, an effect which would render the experiment valueless.

With either of these arrangements the process for determining the amount of ammonia which was contained in the gas tested is the same, and exceedingly simple. Dissolve 530 grains of recently ignited anhydrous carbonate of soda in one decigallon of distilled water (Fig. 10); thoroughly wash out the ammonia tube or tubes, or the Woulfe's bottles and bubbling cylinder, and carefully collect all the washings in one vessel. Fill the burette (Fig. 15), which is divided into 17 equal parts, sub-divided into 10ths, with the soda solution; drop into the vessel containing the washings sufficient infusion of litmus to sensibly change the colour of the liquid, which (if there is, as there should be, an excess of acid) will become red, and place it under the burette. Open the little valve at the bottom of the burette, and allow the soda solution to escape slowly into the vessel containing the washings, which should be kept gently boiling, carefully stirring the while until the colour is restored to a neutral tint, when the liquid will have become neutralized; then close the valve, and, placing the burette in a perfectly upright position, read off the scale upon it, which will indicate in grains the amount of ammonia contained in the gas tested.

Another method of dealing with the washings of the ammonia tubes or apparatus, is to collect them in a beaker, which should be placed in a sand-bath heated moderately, until the whole is evaporated to dryness. The residue will be sulphate of ammonia ($N.H.^4$ $S.O.^4$), 66 parts of which contain 16 parts of ammonia.

Rule.—Multiply the weight of residue by 16, and divide by 66; the quotient is the quantity of ammonia contained therein.

Example.—Suppose 25 feet of gas were passed, and the weight of the residue, after evaporating the washings, is 15·5 grains; then 15·5 × 16 ÷ 66 = 3·7 grains; and as 25 feet : 3·7 grains : : 100 feet : 14·8 grains—the quantity of ammonia contained in 100 feet.

Although the strength of the solution is calculated to detect as much as 17 grains in the 100 feet of gas, it is not advisable to pass above half that quantity through in one experiment, so as to avoid the possibility of any change of colour taking place in the neutral litmus paper in the outlet end of the tube; for should this occur, it would be a sure indication that some of the ammonia had passed off without being neutralized by the acid, and thus render the experiment perfectly useless.

After passing through the meter, the gas may be burnt or otherwise disposed of.

Another Method of Testing for Ammonia by Oxalic Acid.

For this purpose the following solutions are required:—1. A solution of oxalic acid, 100 septems of which are equal to 10 grains of ammonia. 2. A solution of ammonia, of which 100 septems contain 1 grain of ammonia. 3. Tincture of hematine.

The two first solutions may be kept in well stoppered bottles for a considerable period without alteration.

The process is as follows:—

Take two ammonia tubes, filled with small pieces of broken glass, as shown in Fig. 13, and carefully pour into each in the manner described on page 26, 50 septems (Fig. 12), of the oxalic acid solution.

Connect the two tubes together, and with the meter; allow the gas to pass through them until 50 feet is registered on the dial of the meter. Then stop the experiment and wash out both cylinders with distilled water till no trace of acid is left in them.

Collect the washings in a two deci-gallon bottle, and dilute them with distilled water to the mark on the neck of the bottle.

From this fill a 200 septem pipette (Fig. 16), and put this quantity into a beaker, setting the remainder of the liquid aside for other tests, if necessary.

Add to the contents of the beaker 15 drops of tincture of hematine. Take a Mohr's burette, similar to Fig. 15, but containing only 100 septems, graduated from the top downwards, and fill it with the No. 2 or ammonia solution, which is one-tenth the strength of the oxalic acid. Place under it the beaker containing the 200 septems of liquid before spoken of. The colour of this liquid will be of a bright yellow. Now open the valve of the burette, and allow the ammonia solution to drop into the beaker until the yellow liquid therein changes its colour to that of port wine, when the valve must be immediately closed.

During this portion of the experiment the liquid in the beaker must be kept well stirred, so that the alkali may thoroughly combine with the acid, and the ammonia solution must be carefully dropped in, for the hematine test is so delicate that a single drop of the ammonia solution will be sufficient to decide the change in its colour; therefore, unless narrowly watched, the exact point at which the liquid in the beaker becomes neutral may be overlooked, and the experiment rendered thereby defective.

If, however, such an accident should happen, it will only be necessary to take another measure full of the washings contained in the 2-decigallon measure, and repeat the experiment till a satisfactory conclusion is arrived at.

The number of degrees of ammonia solution remaining in the burette are equal to the number of grains of ammonia which have been taken out of the whole quantity of gas operated upon, by merely striking off the decimal point thus:—If the liquid in the burette stands at 80 there were 8 grains of ammonia in the gas; if at 50 there were 5, and so on—no other calculation is required to obtain the result.

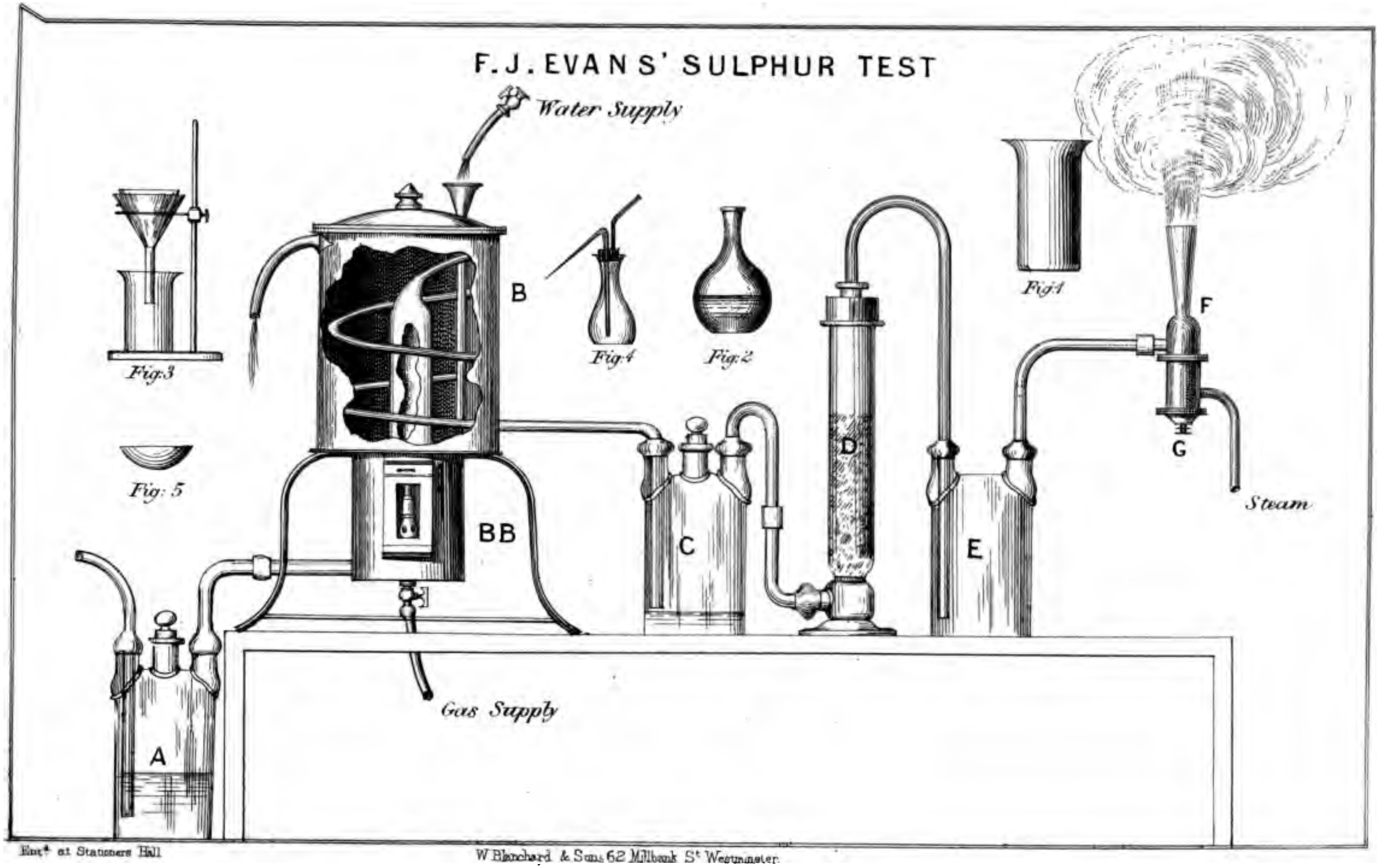
By the kind permission of Mr. John J. Griffin, the following table, which is made use of in the foregoing experiments, is here given in full.

Imperial Liquid Measure, divided decimally by John J. Griffin.

Gallon.	Deci-Gallons.	Centi-Gallons.	Milli-Gallons.	Septems.	Avoirdupois Weight of Water, at 62° F.	
					Grains.	Pounds.
1·	10·	100·	1000·	10000·	70000·	10·
·1	1·	10·	100·	1000·	7000·	1·
·01	·1	1·	10·	100·	700·	·1
·001	·01	·1	1·	10·	70·	·01
·0001	·001	·01	·1	1·	7·	·001

1 Quart = 2500 Septems. 1 Fluid Ounce = 62·5 Septems.
1 Pint = 1250 Septems. 1 Cubic Inch = 36·06543 Septems.
1 Centimetre Cube = 2·2 Septems. 1 Litre = 2·2 Deci-Gallons.

F. J. EVANS' SULPHUR TEST



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W Blanchard & Sons 62 Millbank St Westminster

SULPHUR COMPOUNDS.

F. J. EVANS' APPARATUS AND PROCESS FOR THE ESTIMATION OF SULPHUR IN GAS AFTER THE ORDINARY PROCESS OF PURIFICATION.

The presence of sulphur in the form of sulphuretted hydrogen may be readily ascertained by means of a piece of white blotting paper imbued with acetate of lead, which, upon being wetted and submitted to the action of a stream of gas, becomes discoloured, should there be any appreciable quantity contained therein. But as this form of sulphur impurity is removeable by the ordinary process of purification, it is very rarely to be found in the gas supplied to the public. As, however, other compounds of sulphur exist in gas after the utmost care and trouble have been taken to remove them, and as they defy detection except by a careful analysis, a very ingenious and complete apparatus has been devised by Mr. F. J. Evans, Engineer-in-Chief to the Chartered Gas Company, for the purpose of estimating the whole of the sulphur, in whatever form it may be present, and he has successfully made use of it, with sundry modifications, during more than three years past.

On the next page will be seen an illustration of this apparatus (Pl. 4), and of which the following is a description:—

A is a Woulfe's bottle with three necks, the one to the left being fitted with a tube, which serves as an inlet for atmospheric air, and is made to dip into a solution of caustic potash; the other, to the right, is fitted with a tube only just long enough to enter the bottle, and serves as a conduit to convey to the apparatus all the requisite air, which, being compelled to bubble through the potash, leaves behind it all the sulphur and carbonic acid that might be in combination with the atmosphere before its admission to the bottle.* The upper end of this second tube is attached by means of an india-rubber tube connection to the condenser (B), which consists of a cylindrical chamber, closed both at the bottom and top, save a funnel-shaped inlet and tube outlet to allow of a constant stream of cold water circulating through it. In the centre of the bottom of this chamber a tube, about 2 inches diameter, rises, but is contracted at the top into one of much smaller bore, and is continued in a spiral form around the interior of the cylinder, being finally led out near the bottom. Beneath the cylinder is another chamber, (BB) in which a Bunsen burner is fitted immediately below the central tube before spoken of, so that whatever products of combustion arise from the consumption of gas within this chamber must necessarily pass up the tube and down again through the coil of pipe, all communication with the surrounding air, except through the tube leading from the Woulfe's bottle, being cut off.

---

* The air of large towns is generally found to contain both sulphur and carbonic acid, varying in quantity according to circumstances, but sometimes to a considerable extent.

The termination of the coil of pipe is connected, as shown in the illustration, with another Woulfe's bottle (C), and this, in its turn, is connected with a bubbling cylinder (D), similar to that described when speaking of the test for ammonia. The upper portion of this cylinder, above the bulb, is filled to within about 4 inches of the top with small pieces of broken flint glass—some larger pieces carefully placed above the bulb prevent the smaller pieces from falling down into it. A second Woulfe's bottle (E) is then attached to the bubbling cylinder. This bottle is empty, and serves only to collect any liquid which may be drawn over the bubbling cylinder (D) by the action of the exhauster. From the top of the vessel (E) rises a pipe which is connected with a little piece of apparatus that may be termed an "exhauster," being a small chamber, through an aperture in which (F) a jet of steam blows, and sets in motion a column of air immediately beneath it. This it does with such velocity as to cause a vacuum amply sufficient to suck all the products of combustion evolved from the gas at the Bunsen burner, as well as the air which has supplied the elements of combustion to it, through the several vessels, and finally to discharge them up a chimney or other convenient outlet. A little screw valve (G) is inserted in the bottom of the exhauster to regulate the force of the current, and although the exhauster itself is shown in the drawing close to the rest of the apparatus, it may be placed anywhere, provided a tube large and long enough connects it with the last Woulfe's bottle (E).

The number of bottles and bubbling cylinders may be multiplied if it is supposed that, in consequence of the rapid draught, any of the sulphur may escape.

It is obvious that the greater the quantity of gas per hour which is operated upon, the more need will there be for increasing, in a proportionate degree, the number of bottles and bubbling cylinders.

The apparatus having been fixed in the order pointed out, the mode of operating with it is exceedingly simple, and is this.

Fill the vessel (A) with a saturated solution of caustic potash to such a height that the air inlet-tube may be sealed to a depth of 2 inches. Fill also the cylinder (B) with cold water, and arrange so that a constant stream may be supplied through the funnel at the top. Fill the vessel (C) with a solution of ammonia (strong, specific gravity 880) one inch high. Pour into the bubbling cylinder (D) some distilled water until it rises about ½ an inch above the contraction upon which the broken glass rests.

Make all the connections secure, and then open the lower chamber of the condenser (B) by means of the glass slide. Turn on the steam jet and light the gas as simultaneously as possible, and instantly shut the glass slide. Regulate the consumption by the tap beneath, and the whole will be at once in operation.

The rate per hour of the gas should be regulated by a governor, so that it may not require adjustment after the slide is closed. If this is not done, much trouble is caused by the double adjustment which is required to be made, for then both gas and exhaust must be attended to at the moment of starting.

Care must, however, be taken to adjust the force of the jet of steam by means of the screw (G) before alluded to, so that the vacuum may be strong enough to draw off the products of combustion without putting out the gas.

The consumption per hour may be from 1 to 10 feet, or, in fact, any quantity proportionate to the size of the apparatus, according to the wish of the operator.

Having burned, say, 100 feet of gas, turn off both the steam and the gas. Now comes the process for testing the liquid products of condensation. Empty and wash out with distilled water the vessels C, D, and E, and collect the contents and washings in one vessel. Measure the whole quantity of liquid, and pour a quarter of it into a tall beaker (Fig. 1). Acidify the liquid with a mixture of nitro-muriatic acid (one part muriatic to two parts nitric), or with bromine, till a blue litmus paper dipped into it turns distinctly red.

In adding the acid or bromine care must be taken not to do this too quickly, or the effervescence will cause some of the liquid to be lost.

Bromine water (20 drops pure bromine to 1 ounce of water) will be more easily managed than the pure bromine.

Now pour the contents of the beaker into a bottle (Fig. 2), place it in a sand bath and heat it nearly to boiling, and so keep it until nearly all the fluid has evaporated. All the carbonic acid it before contained will be thus driven off, the residue left being a solution of sulphate of ammonia. Add about one-fourth as much as the bottle will contain of a saturated solution of nitrate of baryta, or chloride of barium (it is unimportant which), and set the whole to cool. As soon as it is cold, the supernatent liquor ought to be poured off without allowing any of the sulphate of baryta precipitated in the form of a white sediment to escape.

If by accident the whole of the fluid should have evaporated, then the sediment must be very carefully washed with distilled water in order to remove any soluble compound which has settled with it.

When all the liquid has run through the paper, take a wash-bottle, containing hot distilled water (Fig. 4), and blow through the upper tube so as to cause a jet of the water to impinge upon the precipitate lying on the paper, in order that whatever soluble matter may remain amongst the particles of sulphate of baryta (which is insoluble) may be dissolved and pass through to the beaker below; and, after folding it in such a manner that no loss of the precipitate may ensue, place it in the crucible, and submit the whole to the flame from the Bunsen burner till it attains, as nearly as possible, a white heat, and keep it so till the paper has been consumed to a whitish ash, after which, allow it to cool.

A very good method of determining whether the washing has been efficiently done, is to test the liquor which passes through the filter, in a test-tube with sulphuric acid, when, if any soluble baryta is present, it will show itself by imparting a milky appearance to the liquid. The washing should be carried on until the water running through the filter is not affected by this test.

Carefully balance in a delicate pair of scales a platinum crucible (Fig. 5), sufficiently large to contain the filter paper. A filter paper should then be prepared, *i. e.*, folded into shape, wetted with distilled water, and placed in a glass funnel, as shown in Fig. 3, and the precipitate poured into it. After pouring out as much as possible, it will be found that there is still some which clings to the sides. This is to be detached by washing the glass repeatedly with distilled water, taking care that the whole of the washings are poured into the filter, the object being of course to collect all the precipitate.

Again, place the crucible in the balance, and ascertain the weight of its contents. Thus the quantity of sulphate of baryta will be found, the weight of the filter paper (if good) being too inconsiderable to be taken into account.

Form of Experiment.

DATE.	TIME.	INDEX OF METER.	
1867. Feb. 8th	11.0 a.m.	100 5	End of Experiment.
„ 7th	10.0 a.m.	Zero.	Commencement of Experiment.
	Consumption, 100·5 cubic feet in 23 hours.		

Quantity of liquid collected	80 oz.
„ „ operated upon . . .	20 „
„ of sulph. baryta collected on filter . .	42 grs.
„ of sulphur contained in 100 cubic feet of gas	**22·97**

117 grains of sulphate of baryta contain 16 grains of sulphur, therefore

Sulphate Baryta.		Sulphur.		Sulphate Baryta.		
As 117·0	:	16·0	::	42×4=168	:	**22·97** grs.

Or, by the use of tables compiled and published by the editor, placed at the end of this chapter, in which the per centage of sulphur may be found by inspection, without the trouble of calculation. Thus,

A fourth part of the liquid collected has been operated upon; therefore, dividing the quantity of gas which has been burnt by 4 (100 feet ÷4=25), opposite the line 25 and under the column 42 will be found the per centage of sulphur in 100 cubic feet of the gas operated upon, viz., **22·779** grs.

The variations, which are unimportant, are caused by fractional differences in the atomic weights made use of by chemical authorities.

DR. LETHEBY'S SYSTEM

OF ASCERTAINING THE QUANTITY OF SULPHUR CONTAINED IN THE GAS SUPPLIED TO THE PUBLIC.

This apparatus is exceedingly simple, and admits of being worked without the aid of an "aspirator," or similar contrivance.

Upon the opposite page (plate 5), is a drawing of one of these instruments, arranged in working order, the apparatus required for the experiment consisting of—

(A) an experimental meter, fitted with an index capable of showing from the one-hundredth part of a cubic foot up to 1,000 cubic feet; a glass water gauge, and lubricators to the bearings of the measuring drum.

(B) a double dry governor, fitted with a regulating cock capable of maintaining an unvarying rate of consumption under the usual street pressures.

(C) a cylinder, 13 inches long, and 4½ inches in diameter, having a neck at each end, 2 inches long, and 2 inches in diameter; at one end is fitted, by means of a well turned and bored cork, a tube (D) ⅜ of an inch in the bore, bent so as to be inclined upwards at an angle of 45° or thereabouts, and at the other, a tube of a trumpet form (E), 3 inches at the bell and ¾ of an inch at the smaller end, inside measure—all in glass, supported upon a wooden stand (FF), made to receive it.

A Leslie burner (G).

A 4-ounce beaker (H) and glass funnel, 3 inches diameter (I), fitted with a tin tube, 3½ inches long, and ½ inch diameter.

A pint measuring-glass (J), divided into 10 parts, subdivided into hundredths.

Two pipettes (K & L).

A wash-bottle (M).

A porcelain evaporating dish (N).

A retort stand (O), fitted with a Bunsen burner (P).

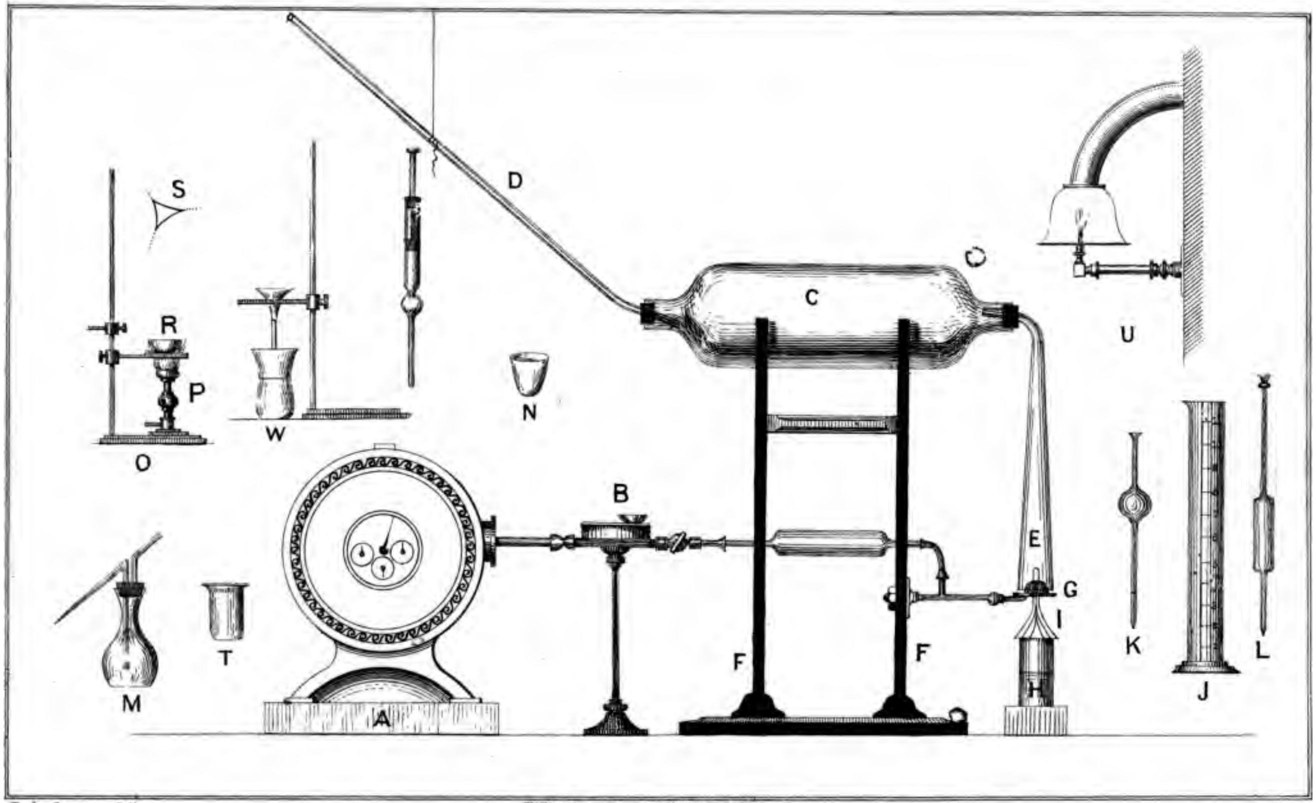
A platinum crucible (R) and platinum wire support (S).

A beaker, from 3 to 4 ounces (T).

The apparatus must be fixed in a room capable of being kept at a temperature not lower than 60° Fahrenheit, free from the sulphur disengaged from fires or gas burning in the room—not

Pl.5

Dr. LETHEBY'S SULPHUR TESTING APPARATUS.



Ent^d at Stationers Hall.

W. Blanchard & Sons, 62 Millbank St Westminster.

heated by a gas stove, and ventilated so that no draught of air should affect the flame or the apparatus.

The bench which carries the apparatus must be supported upon brackets fixed to the wall, or so that it shall at all times be perfectly firm and steady.

The order in which the various parts of the apparatus are arranged is as shown in the drawing, the connections being made with glass tubes, as far as practicable—india-rubber junctions being made use of where necessary.

The meter must be connected to the service by metal pipe.

If there is any difficulty in getting rid of the ammoniacal vapour, which during the performance of an experiment is expelled from the long glass tube (D), the following simple apparatus (U) will be found to answer the purpose.

A bent tube, 2 or 3 inches in diameter, is connected into the chimney or external wall. On the end projecting into the room is attached a glass or copper consumer, of a bell form, inside of which is a jet burner, so arranged that the flame from it when lighted will go a little way up the iron tube. The effect of this arrangement is to induce a current of air up the pipe, and carry off with it the products of combustion, &c.

If the end of the tube (D) be made to discharge about 3 or 4 inches beneath the bottom of the bell, all the fumes will be effectually carried off without affecting in any way the experiment going on.

If the ventilator discharges into the open air, a windguard must be put on the end of the pipe, to prevent the wind from blowing down it.

The apparatus having been properly fixed, the experiment is proceeded with as follows :—

Take off the trumpet tube (E).

Turn on the gas at the inlet of the meter; light the burner (G), and adjust its rate of consumption to 1 foot per hour, or to such a rate as will allow the jets to burn with a yellowish flame at the tips.

The reason for this precaution is, that if the flame is allowed to burn blue, the sulphur contained in the gas will not be burnt at a sufficiently high temperature to be fully oxydised, and therefore, to some extent, it will escape condensation. It is absolutely necessary, for the success of the experiment, that the temperature of combustion be high, and that the heat of the cylinder be also maintained. This latter remark will explain why it is specified that the temperature of the room in which an experiment for sulphur is performed should not be allowed to fall below 60 degrees.

On no account attempt to light the burner without removing the trumpet tube. If the light, through some accident, should go out, the experiment must be recommenced.

Any attempt to relight the burner in any other manner, will probably result in an explosion, and the destruction of the trumpet and exhaust tubes.

Pour into the ammonia beaker (H) 2 ounces of strong liquor ammonia, specific gravity 880.

This quantity of ammonia must be put in for every experiment; any remaining from a previous one must be thrown away, *or put aside for other purposes.*

Place the tube of the funnel (I) through the burner, and support it in its position by placing the ammonia beaker under it, in the manner shown in the drawing.

Replace the trumpet tube, and see that the cork fits properly into the cylinder.

The experiment commences when the trumpet tube is replaced; therefore, as quickly as possible after doing that, take the state of the index of meter and the time by the clock.

The intention of this portion of the experiment is to arrest the sulphurous compounds contained in the gas, the products of the combustion of which are fixed by the ammonia evaporating from the beaker and rising with the current, which is induced up the tube of the funnel (I) by the action of the heat of the burning gas upon it.

This ammonia being carried up the trumpet tube into the cylinder or condenser with the heated air and products of combustion, enters into combination with the burnt sulphur to form sulphite and sulphate of ammonia, which are condensed in the cylinder, either as fine crystals on its upper surface, or dissolved in the water produced by the combustion of the hydrogen of the gas.

No water or wetted cloths are necessary to assist condensation, for, from what has been said above, it will readily be seen that the object of this experiment is not to collect the water formed by the combustion of the gas, but the sulphur acids given off, and that cooling the cylinder will risk an escape of the sulphur.

It being also the intention of this experiment to ascertain the average number of grains of sulphur per 100 cubic feet of gas supplied to the public during the hours of the day and night, it is evident that the best way to arrive at that result is to continue the experiments for 24 consecutive hours, consuming in that time about 25 feet of gas.

If placed as directed, it may safely be left, and will need no attention;

but if, from inattention to the rules given, or from unforeseen causes, the flame has been interfered with or blown about by currents of air, so as to cause a deposit of soot in the trumpet tube or cylinder, the experiment must be looked upon as unreliable, because carbon prevents the complete combustion of sulphur.

The conditions necessary to obtain proper results in this mode of estimating sulphur may be briefly summed up as follows:—

1st. The gas must be burnt at 1 foot per hour, or so that the tips of the jets are of a yellowish colour.

2nd. The combustion must be perfect, so that no soot is deposited in the tube or cylinder.

3rd. The ammonia must be of the highest strength, and sufficient in quantity.

4th. The apparatus must not be used in a cold place.

Allow the experiment to go on for 24 hours, then turn off the gas at the inlet of the meter.

Note the state of the index, and deduct the reading at the commencement of the experiment from it; the difference will be the total consumption during the whole time it has been burning.

Remove the trumpet and exhaust tubes (E) and (D) from the cylinder.

Carefully rinse round the cylinder with the liquid which has accumulated therein, stopping the ends tightly during the operation with corks or the palms of the hands, and pour it into the measuring glass (J).

See that there is no deposit of soot in the inside of the trumpet tube.

If the tube is not blackened, then carefully wash it out with the liquid taken from the cylinder, and pour it back into the measuring glass.

If the amount of the liquid is not enough to divide readily by 10, or if it is supposed that any appreciable quantity of sulphate of ammonia has been left in the cylinder or trumpet tube, then take a sufficient quantity of pure distilled water to fill up the measure to such a mark as will divide, and wash them both with it, pouring the washings into the measure.

Test the liquid for alkaline re-action.

This is done by dipping a piece of reddened litmus paper into the liquid, when, if it is distinctly alkaline, the blue colour of the litmus will be restored. If the liquid is not so, the experiment is a failure, for the strength or quantity of the ammonia could not have been according to the directions given, for the liquid should always smell strongly of ammonia.

The liquid contains the sulphur as sulphate of ammonia, and the method of ascertaining the amount of sulphur contained therein is as follows:—

Measure off one-tenth part of the liquid, pour it into the beaker (T) and evaporate it, without boiling, nearly to dryness.

Add one fluid dram of a saturated solution of bromine in water.

This is made by adding to some distilled water (say 1 ounce) poured into a tightly stoppered bottle 20 drops of pure bromine, and allowing it to stand for 24 hours, till it has taken up as much as it will, leaving a small quantity of bromine at the bottom of the bottle.

Fill up the beaker with hot solution of chloride of barium.

This is made thus—1 ounce avoirdupois of pure chloride of barium to 10 fluid ounces of distilled water made very acid with muriatic acid, added in the proportion of a drachm of acid to an ounce of the solution.

Boil for five minutes, and let it settle; the settlement will be sulphate of baryta.

Add a little more solution of chloride of barium, so as to be certain that the whole of the sulphur has combined with the baryta, which will be shown by the liquid remaining clear. If, on the contrary, it becomes cloudy, let it remain till it again becomes clear.

Pour off as much as possible of the clear liquid into a beaker, without allowing any portion of the precipitate to go with it.

Fold a filter-paper and wet it with distilled water, and place it on a glass funnel held by a filtering stand (W), as shown in the diagram.

Carefully balance, in a delicate pair of scales, the platinum crucible (R).

Wash well, with warm distilled water, the precipitate lying on the filter.

For this purpose use the wash bottle (M), blowing down the upper tube and directing the jet of water expelled from the lower with sufficient force upon the precipitate to wash it without removing it from the filter.

This is done to get rid of any soluble particles which may be mixed with the precipitate, sulphate of baryta being insoluble in water.

Having allowed the water to run through the filter paper, fold it carefully and lay it in the platinum crucible (R), then place the crucible over the Bunsen burner (P), in the manner shown on the drawing.

Light the burner, and burn the whole to whiteness, or till everything combustible has been consumed.

Weigh the residual sulphate of baryta.

Form of Experiment.

DATE.	TIME.	INDEX OF METER.	
1867.			
Jan. 10th	12 . 0 noon	300·32	End of experiment.
„ 9th	11 .25 a.m.	276·35	Commencement of ditto.
		23·97	Consumption in 23 hrs. 25 min.

Quantity of liquid condensed in cylinder made up with distilled water to	20 fluid oz.
Quantity of liquid operated upon . . .	2 „ „
Number of grains sulphate baryta collected on filter	2·8 grs.
Number of grains of sulphur per 100 cubic feet of gas	**15·97**

Example showing the working of the above Experiment.

The quantity of gas burned is 24 ft., and the quantity of liquid condensed in the large glass receiver is made up to 20 fluid oz.

A tenth part of the liquid has been taken to operate upon—2 oz.

The number of grs. of sulphate of baryta collected on filter is 2·8 grs.

First find the quantity of sulphate of baryta in 24 cub. ft. of gas—

2·8 grs. × 10=28 grs.;

then, if there are 28 grs. sulphate baryta produced from 24 ft. of gas, how much will be produced from 100 ft. of the same gas:—

Ft.		Ft.		Grs.		Grs.
24	:	100	: :	28	:	116·6
				S. B.		S. B.

100 grs. sulphate of baryta contain 13·7 grs. of sulphur. So

100	:	116·6	: :	13·7	:	15·97
S. B.		S. B.		S.		

The quantity of sulphur present in the gas experimented upon is therefore shown to have been **15·97** per cent.

Analysis of the Condensed Liquid by Evaporation.

This is as follows:—Take a tenth part of the liquor in the measuring glass (J), and evaporating it to dryness in the beaker (T) at a steam heat, the residue is sulphate of ammonia, which represents very nearly to exactness the amount of sulphur contained in the gas operated upon, for 100 sulphate of ammonia contain 24·3 of sulphur.

In this way sulphur may be determined without the aid of acid or baryta, for the only source of error is a small quantity of nitrate of ammonia formed by the burning gas.

SUGG'S TABLE FOR ASCERTAINING THE PER CENTAGE OF SULPHUR.

Grains of Sulphate of Baryta collected on Filter.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Cubic Feet of Gas consumed.	10	1·355	2·711	4·067	5·423	6·779	8·135	9·491	10·847	12·203	13·559	14·915	16·271	17·627	18·983
	11	1·232	2·465	3·697	4·930	6·163	7·395	8·628	9·861	11·093	12·326	13·559	14·791	16·024	17·257
	12	1·129	2·259	3·389	4·519	5·649	6·779	7·909	9·039	10·169	11·299	12·429	13·559	14·689	15·819
	13	1·043	2·086	3·129	4·172	5·215	6·258	7·301	8·344	9·387	10·430	11·473	12·516	13·559	14·602
	14	·968	1·937	2·905	3·874	4·842	5·811	6·779	7·748	8·716	9·685	10·653	11·622	12·590	13·559
	15	·903	1·807	2·711	3·615	4·519	5·423	6·327	7·231	8·135	9·039	9·943	10·847	11·751	12·655
	16	·847	1·694	2·542	3·389	4·237	5·084	5·932	6·779	7·627	8·474	9·322	10·169	11·016	11·864
	17	·797	1·595	2·392	3·190	3·988	4·785	5·583	6·380	7·178	7·976	8·773	9·571	10·368	11·166
	18	·753	1·506	2·259	3·013	3·766	4·519	5·273	6·026	6·779	7·532	8·286	9·039	9·792	10·546
	19	·713	1·427	2·140	2·854	3·568	4·281	4·995	5·709	6·422	7·136	7·850	8·563	9 277	9·991
	20	·677	1·355	2·033	2·711	3·389	4·067	4·745	5·423	6·101	6·779	7·457	8·135	8·813	9·491
	21	·645	1·291	1·937	2·582	3·228	3·874	4·519	5·165	5·811	6·456	7·102	7·748	8·393	9·039
	22	·616	1·232	1·848	2·465	3·081	3·697	4·314	4·930	5·546	6·163	6·779	7·395	8·012	8·628
	23	·589	1·179	1·768	2·358	2·947	3·537	4·126	4·716	5·305	5·895	6·484	7·074	7·663	8·253
	24	·564	1·129	1·694	2·259	2·824	3·389	3·954	4·519	5·084	5·649	6·214	6·779	7·344	7·909
	25	·542	1·084	1·627	2·169	2·711	3·254	3·796	4·338	4·881	5·423	5·966	6·508	7·050	7·593
	26	·521	1·043	1·564	2·086	2 607	3·129	3·650	4·172	4·693	5·215	5·736	6·258	6·779	7·301
	27	·502	1·004	1·506	2·008	2·510	3·013	3·515	4·017	4·519	5·021	5·524	6·026	6·528	7·030
	28	·484	·968	1·452	1·937	2·421	2·905	3·389	3·874	4·358	4·842	5·326	5·811	6·295	6·779
	29	·467	·935	1·402	1·870	2·337	2·805	3·272	3·740	4·208	4·675	5·143	5·610	6·078	6·545
	30	·451	·903	1·355	1·807	2·259	2·711	3·163	3·615	4·067	4·519	4·971	5·423	5·875	6·327

Note.—Opposite the quantity of Gas consumed, and under the number of Grains of Sulphate of Baryta collected, will be found the number of Grains of Sulphur contained in 100 Cubic Feet of Gas.

SUGG'S TABLE FOR ASCERTAINING THE PER CENTAGE OF SULPHUR.

Grains of Sulphate of Baryta collected on Filter.

Cubic Feet of Gas consumed.	15	16	17	18	19	20	21	22	23	24	25	26	27	28
10	20·338	21·694	23·050	24·406	25·762	27·118	28·474	29·830	31·186					
11	18·489	19·722	20·955	22·187	23·420	24·653	25·885	27·118	28·351	29·583	30·816			
12	16·949	18·079	19·209	20·338	21·468	22·598	23·728	24·858	25·988	27·118	28·248	29·378	30·508	
13	15·645	16·688	17·731	18·774	19·817	20·860	21·903	22·946	23·989	25·032	26·075	27·118	28·161	29·204
14	14·527	15·496	16·464	17·433	18·401	19·370	20·339	21·307	22·276	23·244	24·213	25·181	26·150	27·118
15	13·559	14·463	15·367	16·271	17·175	18·079	18·983	19·886	20·790	21·694	22·598	23·502	24·406	25·310
16	12·711	13·559	14·406	15·254	16·101	16·949	17·796	18·644	19·491	20·338	21·186	22·033	22·881	23·728
17	11·964	12·761	13·559	14·356	15·154	15·952	16·749	17·547	18·344	19·142	19·940	20·737	21·535	22·332
18	11·299	12·052	12·806	13·559	14·312	15·065	15·819	16·572	17·325	18·079	18·832	19·585	20·338	21·092
19	10·704	11·418	12·132	12·845	13·559	14·272	14·986	15·700	16·413	17·127	17·841	18·554	19·268	19·982
20	10·169	10·847	11·525	12·203	12·881	13·559	14·237	14·915	15·593	16·271	16·949	17·627	18·305	18·983
21	9·685	10·330	10·976	11·622	12·267	12·913	13·559	14·205	14·850	15·496	16·142	16·787	17·433	18·079
22	9·244	9·861	10·477	11·093	11·710	12·326	12·942	13·559	14·175	14·791	15·408	16·024	16·640	17·257
23	8·843	9·432	10·022	10·611	11·201	11·790	12·380	12·969	13·559	14·148	14·738	15·327	15·917	16·506
24	8·474	9·039	9·604	10·169	10·734	11·299	11·864	12·429	12·994	13·559	14·124	14·689	15·254	15·819
25	8·135	8·677	9·220	9·762	10·305	10·847	11·389	11·932	12·474	13·016	13·559	14·101	14·644	15·186
26	7·822	8·344	8·865	9·387	9·908	10·430	10·951	11·473	11·994	12·516	13·037	13·559	14·080	14·602
27	7·532	8·035	8·537	9·039	9·541	10·043	10·546	11·048	11·550	12·052	12·554	13·057	13·559	14·061
28	7·263	7·748	8·232	8·716	9·200	9·685	10·169	10·653	11·138	11·622	12·106	12·590	13·075	13·559
29	7·013	7·480	7·948	8·416	8·883	9·351	9·818	10·286	10·753	11·221	11·689	12·156	12·624	13·091
30	6·779	7·231	7·683	8·135	8·587	9·039	9·491	9·943	10·395	10·847	11·299	11·751	12·203	12·655

Note.—Opposite the quantity of Gas consumed, and under the number of Grains of Sulphate of Baryta collected, will be found the number of Grains of Sulphur contained in 100 Cubic Feet of Gas.

SUGG'S TABLE FOR ASCERTAINING THE PER CENTAGE OF SULPHUR.

Cubic Feet of Gas consumed.	Grains of Sulphate of Baryta collected on Filter.												
	29	30	31	32	33	34	35	36	37	38	39	40	41
10													
11													
12													
13	30·247												
14	28·087	29·055	30·024										
15	26·214	27·118	28·022	28·926	29·830	30·734							
16	24·576	25·423	26·271	27·118	27·966	28·813	29·660	30·508					
17	23·130	23·928	24·725	25·523	26·321	27·118	27·916	28·713	29·511	30·309			
18	21·845	22·598	23·352	24·105	24·858	25·612	26·365	27·118	27·871	28·625	29·378	30·131	
19	20·695	21·409	22·123	22·836	23·550	24·263	24·977	25·691	26·404	27·118	27·832	28·545	29·259
20	19·661	20·338	21·016	21·694	22·372	23·050	23·728	24·406	25·084	25·762	26·440	27·118	27·796
21	18·724	19·370	20·016	20·661	21·307	21·953	22·598	23·244	23·890	24·535	25·181	25·827	26·472
22	17·873	18·489	19·106	19·722	20·338	20·955	21·571	22·187	22·804	23·420	24·036	24·653	25·269
23	17·096	17·686	18·275	18·865	19·454	20·044	20·633	21·223	21·812	22·402	22·991	23·581	24·170
24	16·384	16·949	17·514	18·079	18·644	19·209	19·773	20·338	20·903	21·468	22·033	22·598	23·163
25	15·728	16·271	16·813	17·355	17·898	18·440	18·983	19·525	20·067	20·610	21·152	21·694	22·237
26	15·123	15·645	16·166	16·688	17·209	17·731	18·252	18·774	19·295	19·817	20·338	20·860	21·381
27	14·563	15·065	15·568	16·070	16·572	17·074	17·576	18·079	18·581	19·083	19·585	20·087	20·590
28	14·043	14·527	15·012	15·496	15·980	16·464	16·949	17·433	17·917	18·401	18·886	19·370	19·854
29	13·559	14·026	14·494	14·961	15·429	15·897	16·364	16·832	17·299	17·767	18·234	18·702	19·170
30	13·107	13·559	14·011	14·463	14·915	15·367	15·819	16·271	16·723	17·175	17·627	18·079	18·531

Note.—Opposite the quantity of Gas consumed, and under the number of Grains of Sulphate of Baryta collected, will be found the number of Grains of Sulphur contained in 100 cubic Feet of Gas.

SUGG'S TABLE FOR ASCERTAINING THE PER CENTAGE OF SULPHUR.

Cubic Feet of Gas consumed.	Grains of Sulphate of Baryta collected on Filter.												
	42	43	44	45	46	47	48	49	50	51	52	53	54
10													
11													
12													
13													
14													
15													
16													
17													
18													
19	29·973	30·686											
20	28·474	29·152	29·830	30·508									
21	27·118	27·764	28·410	29·055	29·701	30·347							
22	25·885	26·502	27·118	27·734	28·351	28·967	29·583	30·200					
23	24·760	25·350	25·939	26·529	27·118	27·708	28·297	28·887	29·476	30·066			
24	23·728	24·293	24·858	25·423	25·988	25·553	27·118	27·683	28·248	28·813	29·378	29·943	30·508
25	22·779	23·322	23·864	24·406	24·949	25·491	26·033	26·576	27·118	27·661	28·203	28·745	29·288
26	21·903	22·425	22·946	23·468	23·989	24·511	25·032	25·554	26·075	26·597	27·118	27·640	28·161
27	21·092	21·594	22·096	22·598	23·101	23·603	24·105	24·607	25·109	25 612	26·114	26·616	27·118
28	20·338	20·823	21·307	21·791	22·276	22·760	23·244	23·728	24·213	24·697	25·181	25·665	26·150
29	19·637	20 105	20·572	21·040	21·507	21·975	22·442	22·910	23·378	23·845	24·313	24·780	25·248
30	18·983	19·435	19·886	20·338	20·790	21·242	21·694	22·146	22·598	23·050	23·502	23·954	24·406

Note.—Opposite the quantity of Gas consumed, and under the number of Grains of Sulphate of Baryta collected, will be found the number of Grains of Sulphur contained in 100 cubic Feet of Gas.

SUGG'S TABLE FOR ASCERTAINING THE PER CENTAGE OF SULPHUR.

Grains of Sulphate of Baryta collected on Filter.

Cubic Feet of Gas consumed.	55	56	57	58	59	60	61	62	63	64	65	66	67
10													
11													
12													
13													
14													
15													
16													
17													
18													
19													
20													
21													
22													
23													
24													
25	29·830	30·372											
26	28·683	29·204	29·726	30·247									
27	27·620	28·123	28·625	29·127	29·629	30·131							
28	26·634	27·118	27·602	28·087	28·571	29·055	29·539	30·024					
29	25·715	26·183	26·651	27·118	27·586	28·053	28·521	28·988	29·456	29·923	30·391		
30	24·858	25·310	25·762	26·214	26·666	27·118	27·570	28·022	28·474	28·926	29·378	29·830	30·282

Note.—Opposite the quantity of Gas consumed, and under the number of Grains of Sulphate of Baryta collected, will be found the number of Grains of Sulphur contained in 100 Cubic Feet of Gas.

ILLUMINATING POWER.

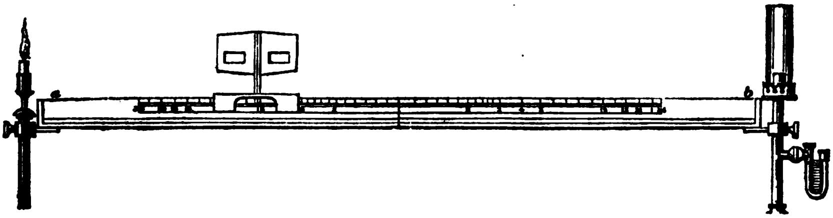
We will now proceed to examine the illuminating power of the gas by means of the photometer.

The photometer is, as its name implies, an instrument for determining the amount of light given by any illuminating agent, in terms of some other agent, and its construction depends upon the well-known law of optics, that the quantity of light thrown upon an object by any luminous body is inversely as the square of the distance. In order to make this clear, let us suppose a disc of paper to be placed in a vertical position, one hundred inches from a candle, on the same level; if the candle be lighted, the paper will be illuminated on the side facing the candle, with a certain quantity of light; let the candle and the disc be now placed fifty inches apart, half the original distance, and the paper will be then illuminated with four times the quantity of the first position; if placed at thirty-three and one-third inches, or one-third the original distance apart, the light will be increased to nine times and so on, as shown more clearly in the following table:—

If at 100 inches apart, the light be taken as 1.
at 50 inches or $\frac{1}{2}$, it will be 4, the square of 2 being 4.
at 33$\frac{1}{3}$ „ or $\frac{1}{3}$ „ $3 \times 3 = 9$.
at 25 „ or $\frac{1}{4}$ „ $4 \times 4 = 16$.
at 20 „ or $\frac{1}{5}$ „ $5 \times 5 = 25$, &c., &c.

In applying this beautiful law to determine the illuminating power of any light-giving agent, an instrument of most careful and accurate construction is absolutely necessary. The first photometer was made, I believe, by Count Rumford, who adopted the plan of adjusting the lights, at such a distance from an upright rod, that the shadow produced by each on a white screen should be equal. He then measured the distances of the lights from the rod, and the larger number of inches squared, divided by the smaller number squared, gave the illuminating power of the greater light in terms of the lesser. But this method soon gave way to a much more simple and accurate process, devised by Bunsen. If a piece of white paper be saturated with melted spermaceti, it becomes translucent, and if a spot be left untouched in its centre about the size of a shilling, we shall find that when examined by reflected light—that is, light from the same side as the observer—the disc will look white and the surrounding part dark; but if the observer shift his position to the opposite side, and examine the paper by transmitted light—that is, light from the opposite side of the instrument—the disc will appear dark, and the surrounding part light and translucent. Lastly, if two lights of equal intensity are placed one on each side of the paper, the disc will disappear, for then the light from one side neutralizes the light from the other, and there is no disposition to produce either effect. This is the principle of Bunsen's photometer, which, as originally constructed by Mr. King of Liverpool, consisted of a simple bar of wood placed with its edge uppermost, and firmly supported at both ends; the gas to be tested was burned at one end and the candle at the other, a circular disc of paper being fitted to a socket and made to slide freely up and down the bar, so that when placed in such a position that the light from the gas was equal to the light from a candle, the value of the gas in terms of the candle might be read off on a scale attached.

The method by which the scale of this instrument is computed is as follows:—Let us suppose *a*, *b*, to be the beam, and *x*, the distance from the candle to the disc, *n*, being the number of candles to which the gas is equal.



Thus n, multiplied by x^2, is equal to the candle or unity multiplied by $(100-x)^2$; or, putting it in the form of an equation, we have

$$nx^2=(100-x)^2$$

$$nx^2=100^2-200x+x^2;$$

or,

$$nx^2+200x-x^2=100^2$$

$$nx^2-x^2+200x=100^2$$

$$(n-1)x^2+200x=100^2$$

$$x^2+\frac{200}{n-1}x=\frac{100^2}{n-1}.$$

Completing the equation,

$$x^2+\frac{200}{n-1}x+\frac{100^2}{(n-1)^2}=\frac{100^2}{n-1}+\frac{100^2}{(n-1)^2}$$
$$=\frac{100^2(n-1)+100^2}{(n-1)^2}$$
$$=\frac{100^2n-100^2+100^2}{(n-1)^2}$$
$$=\frac{100^2n}{(n-1)^2};$$

and extracting the root,

$$x+\frac{100}{n-1}=\frac{100\sqrt{n}}{n-1};$$

that is,

$$x=\frac{100(\sqrt{n}-1)}{n-1}.$$

Having now found the value of x in terms of the candle, let us suppose the gas equal to 9 candles; then, substituting 9 for n in the above equation, we have

$$x=\frac{100(\sqrt{9}-1)}{9-1}=$$
$$=\frac{100(3-1)}{9-1}$$
$$=\frac{100\times 2}{8}=25 \text{ inches};$$

or, in other words, if the disc be 25 inches from the candle in the 100-inch beam photometer, the gas will be giving a light equal to 9 such candles—the gas being exactly three times as distant from the disc as the candle.

Opposite this page is a drawing (Pl. 6), of the Bunsen photometer, as improved by Mr. Alfred King, of Liverpool, with the apparatus he employed, consisting of the photometer beam, as described, supported upon two pillars, and carrying upon it a saddle or slide, upon which was fixed the disc held by a brass rim. A pointer screwed to the slide immediately under the disc showed upon the scale the position of the disc with regard to the gas and candle. The meter for registering the rate per hour at which the gas was consumed, was made of the capacity of one-tenth of a foot per revolution of the measuring drum, one of these revolutions per minute being equal to the rate of 6 cubic feet per hour, so that by

taking an observation of one minute, the rate per hour of a burner could be easily ascertained.

For maintaining an uniform rate of pressure during his experiments, he contrived a small and delicate governor, made upon the principle invented by Clegg, with a very small long cone. The gas-holder of this instrument was counterbalanced by weights at the end of a long beam, each end of the beam being the segment of a circle, the centre of which was also the centre of the beam. By this arrangement the weights and the gas-holder were always equi-distant from the point of suspension.

The duration of the experiment was shown by a clock with a 40-inch pendulum, and 30-pin escapement, so that the minute hand attached to the scape-wheel made one revolution per minute. To the shaft of this scape-wheel he fitted a snail in such a manner that a small hammer was lifted by its revolution, and allowed to fall upon a bell at the end of every minute. The experimenter was thus warned when to mark the position of the gas hand upon the dial of the meter at either the commencement or termination of an experiment.

The pressure gauge, also contrived by him, and now commonly known as "King's Pressure Gauge," was made upon the principle of the ordinary inverted syphon, the leg or well open to the atmosphere being sufficiently enlarged to admit of a small float rising and falling without adhering to the side of the tube. Above the well, and with its edge over the centre of the opening, was fixed a wheel, the circumference of which was double, or rather more than double the length of the extreme height to which the water could rise or fall. Over the grooved periphery of the wheel a light line was passed, one end being attached to the float and the other to a counterpoise, consequently any motion in the water was imparted through the line and float to the wheel. Upon the shaft of this wheel a pointer was fitted, the length of which magnified the motion of the wheel, so that the rise of an inch of water in the well was shown upon a much increased scale on a dial supported by a pillar on each side of the well, the centre of the dial being also the centre of the wheel.

The burner he used as a standard was, in all probability, a 15 or 30-hole argand, with cones, as shown in Clegg's Treatise on Gas. In the 3rd edition of this work in 1859, it was, however, depicted as with a fish-tail burner. Be this as it may, no sort of attention appears to have been paid to the kind of burner employed, because in practice, up to 1860, any kind of burner—Leslie's, thirty-hole, national, argands, with and without cones; in fact, almost every variety of burner was used, according to the pleasure of the experimenter. The only thing that was constant, was the rate, that of 5 cubic feet per hour.

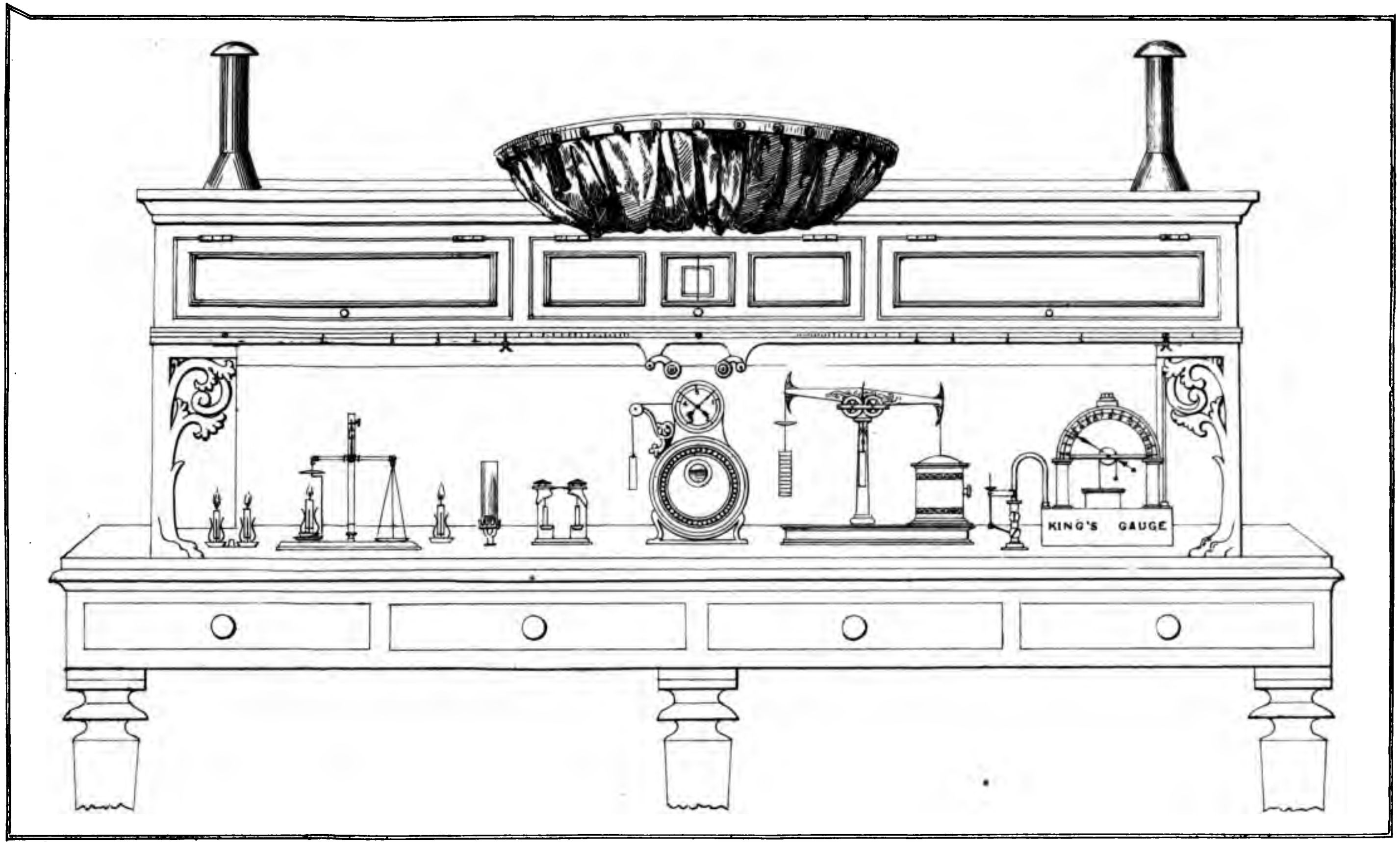
Added to this the photometer was designed to be placed and used in an apartment, the entire surface of which was to be coloured of a dead black, so that no reflection from any part of the room should affect the experiment. But, as no specific rule was laid down as to the size of the room, or the distance from the wall, it resulted from the combination of these and other omissions that the best and most careful experimenters differed as much as 25 per cent. in their estimate of the value of what was commonly termed 12-candle gas. These enormous variations and uncertainties were become so patent, that Mr. F. J. Evans, then Superintendent of the Westminster Station of the Chartered Gas Company, was induced to turn his attention to the matter, and the consequence was the invention of the Photometer which bears his name, and which is at this time so well known.

The particular circumstance which led to the invention of the Evans Photometer, was the want of an instrument which could be employed to test the actual amount of light given by a public lamp, *in situ*, as compared with a standard sperm candle. This want was felt, in consequence of a dispute which had arisen between the Gas Company and their customers, the parishes of St. Margaret and St. John, Westminster; and the first of these instruments, in the form of a long box lined with black cloth, was used to test the light given by a gas lamp, burning under ordinary circumstances in the public street.

The success of this experiment clearly demonstrated the value of an instrument, which, by protecting the eyes of the operator from the glare of the lights, enabled him accurately to determine their relative values, while, at the same time, in all experiments performed by the aid of this instrument, gases or burners tested were placed in similar circumstances with regard to each other and the standard candle, whether the experiment was conducted in the streets, or in a photometer room. Accordingly, one was

Pl 7

PHOTOMETER — F. J. EVAN'S SYSTEM



Entᵈ at Stationers Hall

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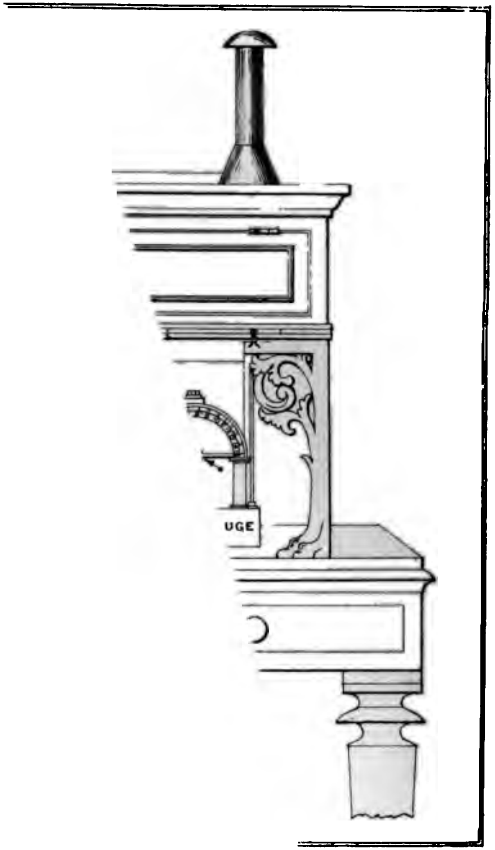
SYSTEM



immediately made and put into operation at the Westminster station, where it still remains, with but few modifications, and is at the present time used for testing the cannel and common gas as supplied to the public from those works.

The introduction of this photometer led to the improvement of other parts of the apparatus requisite in testing for illuminating power. The advent of the Metropolis Gas Act rendered it absolutely necessary that some form of apparatus should be immediately adopted, by the use of which the testers appointed under the Act might agree in their results with those obtained by other instruments in different places. This caused a critical examination to be made of the entire system, and, as a consequence, the almost general adoption of one form of apparatus and course of procedure, which, although not perfect, is not altogether unsatisfactory. A few alterations, not great or difficult, would doubtless place the English method on such a footing as to be both thoroughly reliable and second to none in point of practical utility.

THE EVANS PHOTOMETER.

This instrument, as at present manufactured (Pl. 7), consists of a long box made of dry pine, French polished on the outside, lined within with black velvet, and provided with three doors, which equally divide the entire length of the front. The central panel of the middle door is filled with clear plate-glass to enable the operator to see the disc without disturbing the lights burning in the Photometer, and is of such dimensions that he cannot obtain a view of it from a greater angle than 45°, or thereabouts. The disc is fixed into a moveable plate that slides in a transverse groove from back to front, and occupies the exact centre of the box; at the same time it divides the box into two distinct chambers, so that no rays of light can pass from one to the other except through the disc. The other two doors are for the purpose of allowing ready access to the candles or gas light, in whatever position they may happen to be.

Each chamber is provided with an arrangement by which the two lights to be compared can be made to slide from the end towards the centre, or *vice versâ*, at the pleasure of the operator, while a proper amount of fresh air is admitted without allowing the entrance of day or other external light. For this purpose wooden slides, fitted with brass tubes, are placed so as to slide in slots cut longitudinally through the bottom of each chamber. To the bottom of the photometer, and attached to each chamber, is a pair of wheels, one wheel being fixed near the centre and the other at the end of their respective chambers. Over each pair of wheels an endless cord passes, and the middle of the cord is made fast to the wooden slide which carries the light. A handle is fixed to each of the wheels nearest the centre, which, upon being turned by the operator, causes the light in connection with it to approach to, or recede from, the disc. These two actions are covered by boxes having wooden light guards or screens running longitudinally, and from the bottom of the boxes project the ends of the brass tubes before spoken of, which serve to convey gas to each end of the photometer.

The heated air and products of combustion are carried off by means of a copper funnel fixed at each end of the instrument, assisted by a ventilating roof so arranged as to exclude external light.

The scale is attached in front, immediately below the doors, and a pointer fixed exactly in the centre of the wooden slide, shows upon the scale the corresponding position of the light within. These photometers are made according to circumstances, 100, 75, 50, or any other number of inches, calculating from end to end of the scale.

In this instrument the distance from the greater light to be compared is a constant quantity, that of the lesser light being alone variable; because, the disc being fixed, it is necessary to bring the weaker light nearer to it in order that it may be illuminated to the same degree as it is by the more powerful one. Whatever the lights used may be, whether that of candles, gas, or oil, the rule for calculating the scale remains the same; and, in order to show by example how this is worked out, let it be supposed that a gas burner is fixed at 50 inches from the disc on the one side, and that, to give an equal amount of light on the opposite, it has been necessary to advance the candle to within 16⅔ inches (16·66) on the other. Then, to ascertain how many candles the gas is equal to, it is only needful to square the distances of the gas and candle from the disc, and divide the greater by the smaller, and the result is attained. Thus—

$$\begin{array}{r}
16{\cdot}66 \\
16{\cdot}66 \\
\hline
9996 \\
9996 \\
9996 \\
1666 \\
\hline
277{\cdot}5556
\end{array}
\quad) \quad
\begin{array}{r}
50 \\
50 \\
\hline
25000000{\cdot}00 \\
24980004\phantom{{\cdot}00} \\
\hline
\ldots 19996\ 00
\end{array}
\quad (\quad
\begin{array}{l}
\textit{Answer.} \\
9{\cdot}07
\end{array}$$

Practically, then, the gas would, in this case, be equal to 9 candles.

The following is the formula used to work out the divisions on the scale. Let n be the number of candles the gas is equal to, and x the distance from the candle to the disc; then, bearing in mind what has been said before, the proposition may be put thus:—

If (n) candles (the number to which the gas is equal) require 50 inches, what distance (x) is required for one candle? The equation is, therefore,

$$n : 1 :: 50^2 : x^2;$$

$$\text{or, } nx^2 = 50^2.$$

Suppose $n=9$, then

$$9x^2 = 50^2,$$

$$x^2 = \frac{50^2}{9}.$$

Extracting the root on both sides, we get

$$x = \frac{50}{3} = 16{\cdot}66 \text{ inches.}$$

That is, if the candle be 16⅔ inches from the disc, the gas is equal to 9 candles; and so on, by substituting for n the numerical value of the gas in candles, the several points in the scale are determined.

Among the advantages possessed by this Photometer, in consequence of the disc being fixed in the centre of the scale, and the lights at either end to be compared being moveable, is its adaptability to a great variety of experiments.

These include the estimation of the illuminating power of gases, either as compared with the sperm candle or other standards, or with one another, and the estimation of the value of different kinds of burners of all sizes, consuming the same or different gases, whether of high or low illuminating power. Thus, supposing it is required to test two small burners, which eliminate but little light, in a 100-inch photometer, the disc will be so faintly lighted on either side, if the burners are 100 inches apart, as of course they must be with a Bunsen photometer, that great difficulty will be experienced in arriving at a just conclusion; whereas, with the Evans' photometer, the matter would be very easy, for on moving one of the lights up to the 10 on the scale, the question would be this: How many of the one-light will be required to equal 10 of the other? and by then moving the latter until the disc was equally illuminated, the answer might be read off the scale without further calculation. Now even this experiment, if performed by the Bunsen photometer, would necessitate a calculation, in order to get the requisite result, and should the lights be nearly equal, the imperfect illumination of the disc would render the experiment a doubtful one.

If, on the other hand, the burners are of a larger size, they may be tested in the usual manner, or in the way indicated above, at the option of the experimenter.

It will, however, tend to the elucidation of the directions given in the following pages, if a description is now given of the apparatus which serve as auxiliaries to the photometer, more especially as some of them must be used with any photometer, whatever its construction may be.

METER AND CLOCK.

All recent Acts of Parliament relating to the supply of gas in England specify that the standard of comparison shall be a sperm candle consuming 120 grains per hour, and that the gas shall be burnt either through an argand burner having 15 holes in the ring, and fitted with a 7-inch chimney, or a fishtail or batswing, according to whether it is common or Cannel gas. As an illustration it may not be out of place to quote the Metropolis Gas Act, 1860, the 25th clause of which provides, so far as London is concerned, that

ESTIMATION OF THE ILLUMINATING POWER OF COAL GAS BY COMPARISON WITH A SPERM CANDLE.

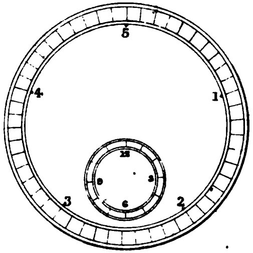


Fig. 1.

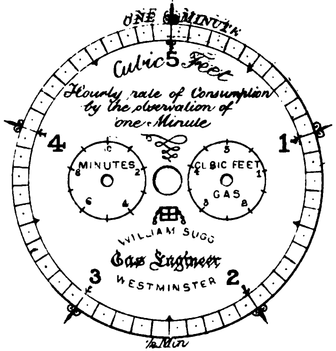


Fig. 2

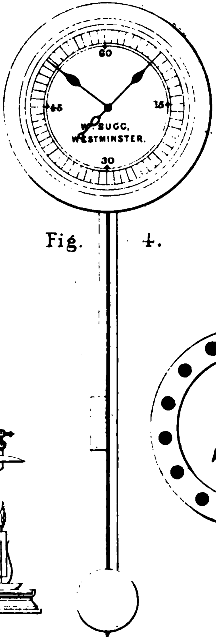


Fig. 4.

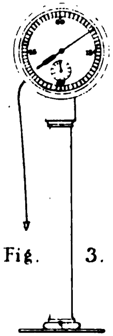


Fig. 3.

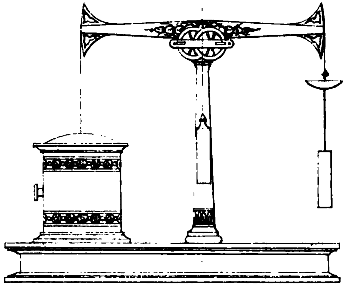


Fig. 5.

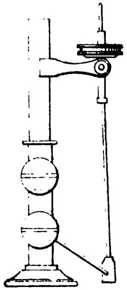


Fig. 6.

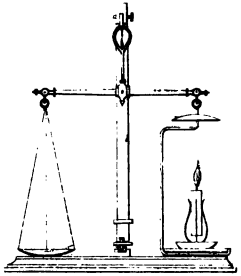
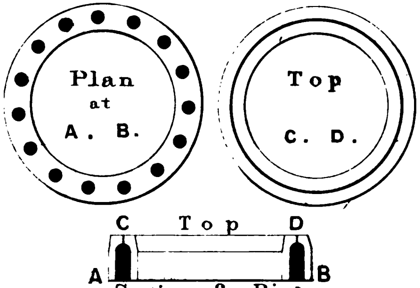


Fig. 7.



Section of Ring

Fig. 8.

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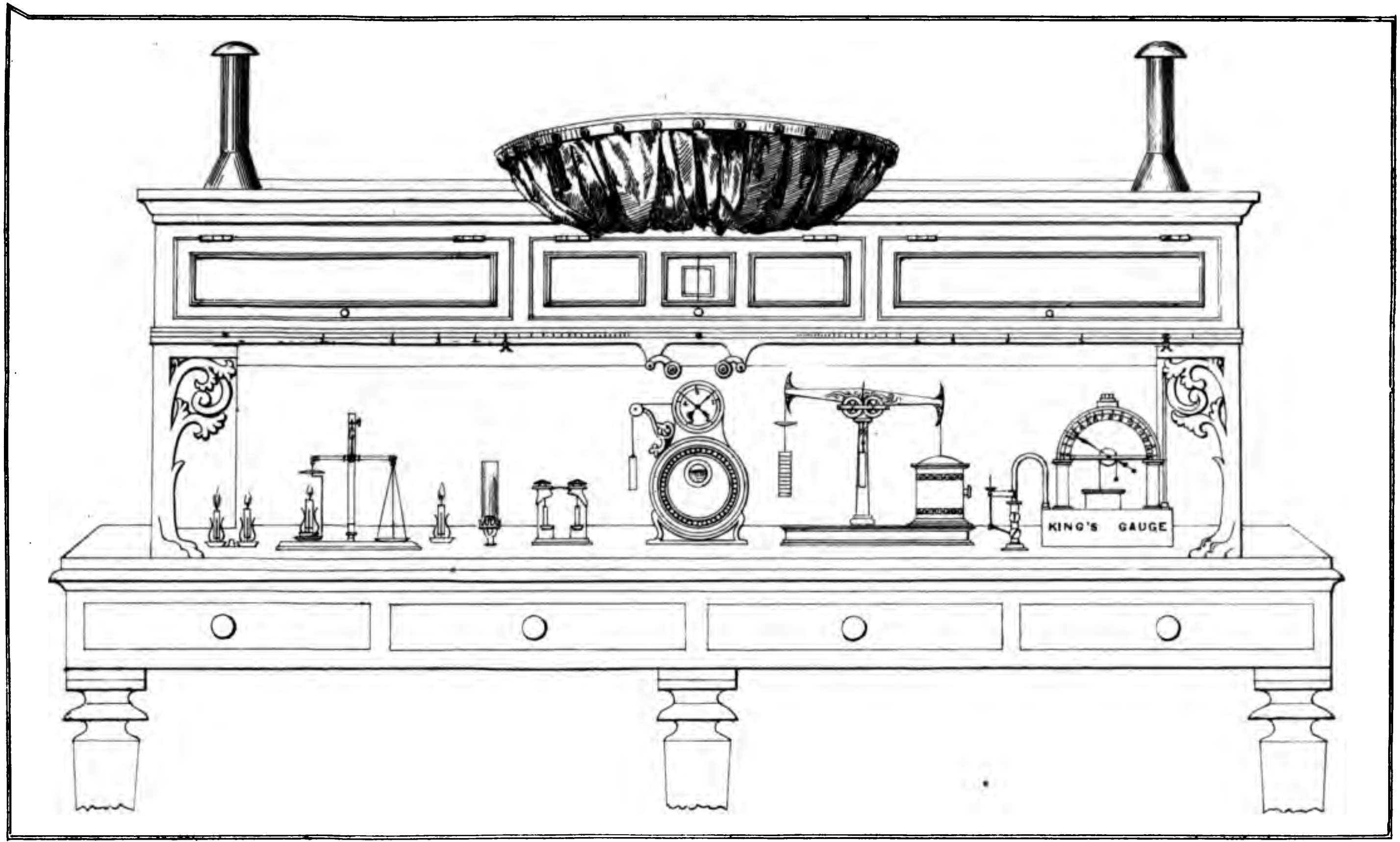
Now, in [illegible] movement under [illegible] it will [illegible] which [illegible] twelfth [illegible] measuring drum [illegible] will be equal [illegible] of the [illegible] spaces, represe[illegible] Fig. [illegible]. It [illegible] ascertained [illegible] during the [illegible] shows a dial [illegible] cubic feet, and [illegible] divided into 12 [illegible] measuring drum [illegible] foot, correspo[illegible] measuring dr[illegible] twelfth of the [illegible] consequently one [illegible] [illegible]

In order that the [illegible] known and easily [illegible] true water li[illegible] [illegible]

Pl 7

PHOTOMETER — F. J. EVAN'S SYSTEM



Ent^d at Stationers Hall

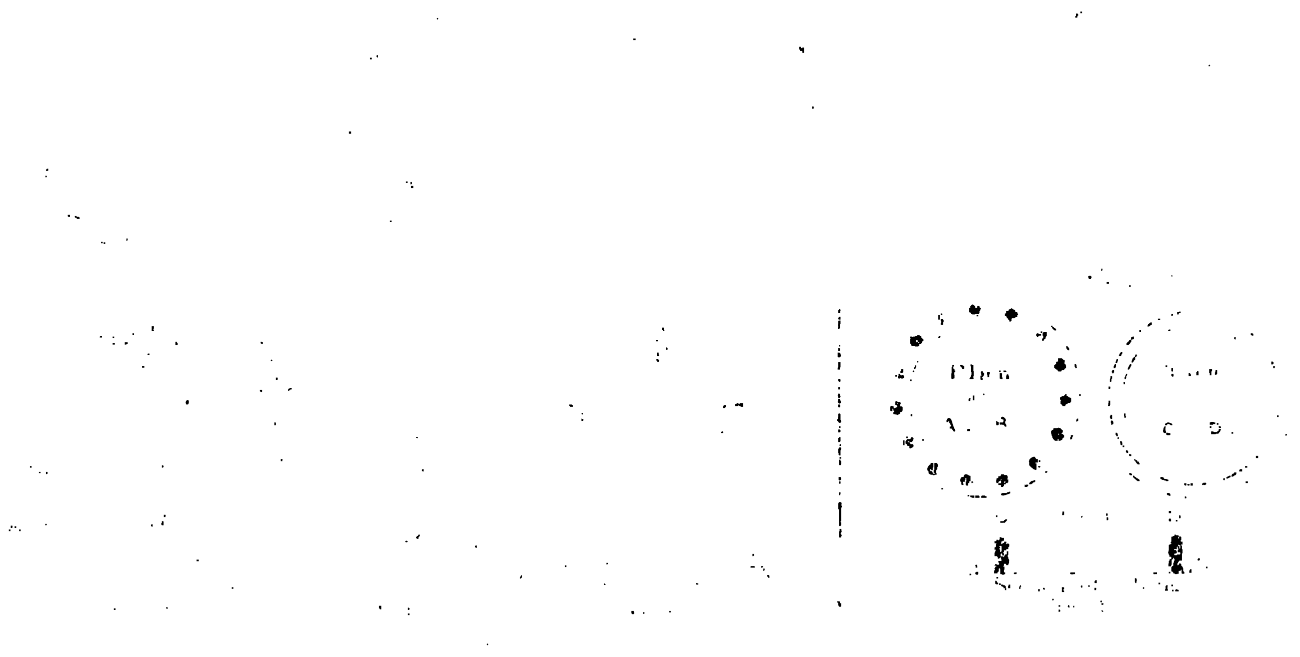
W. Blanchard & Sons 62 Millbank S^t Westminster [illegible] the use of wi[illegible]

[illegible]E EVANS PH[illegible]

[illegible] at present [illegible] of dry plate, French [illegible] black velvet, and [illegible] door is [illegible] lights burning [illegible] of [illegible] obtain greater [illegible] movable plate that slides [illegible] transverse front, and [illegible] the [illegible] centre [illegible] divides th[illegible] can pass [illegible] their two [illegible] candle[illegible]

ES [illegible] ING PR [illegible]

[illegible]



> " The quality of the common gas supplied by any Gas Company shall be, with respect to its illuminating power at a distance as near as may be of one thousand yards from the works, such as to produce from an argand burner having fifteen holes and a seven-inch chimney consuming five cubic feet of gas an hour, a light equal in intensity to the light produced by not less than twelve sperm candles of six to the pound, each burning one hundred and twenty grains an hour; and the quality of Cannel gas supplied by any Gas Company shall, with respect to its illuminating power at the distance aforesaid, be such as to produce from a batswing or fishtail burner, consuming five feet of gas per hour, a light equal in intensity to twenty such sperm candles."

Now, in order to perform an experiment under these conditions, it will be necessary to provide a meter which will register one-twelfth of a cubic foot in one complete revolution of the measuring drum, because one-twelfth of a cubic foot per minute will be equal to 5 cubic feet per hour, the standard quantity. The dial of the meter for this experiment need only be divided into 5 spaces, representing cubic feet subdivided into tenths (see Pl. 8, Fig. 1). It should also be provided with an arrangement for ascertaining the number of revolutions which the meter has made during the time occupied in performing an experiment. Fig. 2 shows a dial with the outer circle divided into 5 spaces called cubic feet, and subdivided also into tenths, the inner circle being divided into 12 parts. The pointer, which is connected with the measuring drum, makes one revolution for every one-twelfth of a foot, corresponding exactly, therefore, with the revolution of the measuring drum. The pointer of the smaller circle moves one-twelfth of the entire circumference at each revolution of the drum, consequently one cubic foot of gas passed through the meter will cause it to complete the circuit of the dial.

In order that the water line of the meter may be always known and easily corrected, a water gauge is attached, and the true water line marked thereon. This is the best method, for, if a run-off plug only is used, it becomes necessary to know exactly how long the plug is to be left open, otherwise more or less water may flow off than intended, and will thus vary the standard quantity that was in the meter at the time of its being proved. Any variation in this respect, which is very likely to occur with so imperfect an adjustment, would render the experiment inaccurate.

Lubricators should be fitted to the front and back bearings of the shaft of the measuring drum, for the instrument is only correct when the working friction is the same as at the time it was proved. Stiffness in the bearings has the effect of making the meter register slow, the capacity of the measuring drum being increased by the greater pressure required to move it.

That portion of the bench upon which the meter is to stand should be accurately levelled. This will be found more convenient than having levels and screws attached to the meter, as these tend to complicate the instrument.

As in all Acts of Parliament relating to gas, as well as in the one already quoted, the rate per hour at which the gas and candle are to be consumed is specifically defined, it will be seen that time is an important element in a photometrical experiment.

Now a reference to Plate 8 (Fig. 2) will shew that, as the circumference of the dial is divided into five parts, which are called cubic feet, and as the pointer of the large circle so divided completes its circuit when the twelfth of a cubic foot of gas has passed through the meter, it is evident that the index multiplies that quantity by 60, *i.e.* $12 \times 5 = 60$; for it would really require 60 revolutions of the measuring drum to pass 5 cubic feet, the quantity shown on the dial. The distance, therefore, travelled over by the pointer during the space of one minute will indicate the exact quantity which would be passed through the meter in one hour if it were kept moving at the same rate. A clock which will accurately define one minute, and is provided with an arrangement for starting and stopping instantly, is therefore indispensable. This is required to ascertain the rate of the consumption not only of the gas, but also of the candle; and as it would be very difficult to ascertain the consumption of one or two candles, and observe the illuminating power of the gas in one minute, a certain number of minutes must be taken, so that a proper average of the consumption of the candle may be arrived at. Practice has shown that the best experiments are performed in 10 minutes (although some operators prefer 12 or 15); therefore the clock should have, besides the minute hand, an arrangement for showing how many minutes have elapsed from the commencement to the end of an experiment. An error in this would give a wrong average of the consumption of the candle, and a much more magnified error in the illuminating power of the gas.

Fig. 2 shows the dial of an index combining the whole of these requirements, made by the editor upon a suggestion by Mr. Douglas, Superintendent of the Phœnix Gas Works, Vauxhall, and which is that now most generally used in this country. In this index the outer circle is divided into five parts, called 5 cubic feet. The right hand small circle is divided into five parts, subdivided into tenths, and one complete circuit of this dial is made for every actual 5 cubic feet passed through the meter.* The left hand circle is divided into ten parts, each part representing one minute of time.† There are two long pointers to the outer circle, the thinnest one being the minute hand of the clock, which completes its circuit in one minute, and, for each revolution of this hand, the pointer of the left hand circle moves on one division.

Motion is given to the two gas hands by means of a connection with the measuring drum, and to the two time hands by a small lever escapement clock working in the same frame with the index, but entirely independent of it. The motive power of the clock is a small weight attached to a line coming out from the side of the index, and running over a pulley secured to a bracket projecting from the side of the index box of the meter. The weight has been adopted in preference to a spring because of its more even and perfect action. In the interior of the index is fixed a little bell, and a lever, raised by a snail attached to the scape-wheel, causes a hammer to strike the bell as the minute hand completes its revolution. A small lever, the end of which projects from the index box at top, serves to start or stop the clock, as required, and a light cord hanging down on the left side of the meter is used to wind up the clock and bring back the 10-minute hand to zero.

When the meter has not this kind of index a separate minute clock is made use of; either a small lever clock similar to the one described in the combination index, (Fig. 3) or a large clock with a 40-inch pendulum. The inconvenience attending the latter is the difficulty of properly starting and stopping it instantly. The small one, however, is not open to this objection, and is made so as to stand level with the dial of the meter.

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* This dial would be better if divided into twelve, and one complete circuit equalled one cubic foot; but, as all meters of this kind at present employed are arranged differently, it was thought better to describe one as now in use.

† This is arranged for 10-minute observations. For experiments of longer duration the circle is divided into 15 minutes.

GOVERNOR.

The variations of pressure always occurring on any main to which a photometer may be connected, would, in all probability, so affect the consumption of the test burner that the experiment would be rendered valueless, unless some instrument were interposed between the meter and the gas burner, which of itself would regulate and maintain a constant pressure at the point of ignition. This work is effectually performed by the governor, Pl. 8, Fig. 5, which is an instrument made on the same principle as those commonly in use at gas works for regulating the delivery into the street mains, but with a very much more delicate action.

The tank and gas-holder are of such depth as to contain sufficient water to bear a pressure of 6 inches without blowing. The cone is long and small in diameter, so that the slightest increase or decrease in the consumption at the burner may cause a perceptible movement in the gas-holder. The beam is of the kind termed fish beams, because the body and ends bear some resemblance to the body and tail of a fish. Each end forms the segment of a circle, the radius of which is found in the middle of the beam, and through this the gudgeon passes upon which it hangs and rocks. This form is adopted in order that at any portion of the stroke of the governor, the line supporting the gas-holder, as well as that carrying the balance weights, may always hang at the same distance from the centre. By this means, in whatever position the gas-holder and cone may be, the counterbalance weights will maintain very nearly the same relation to them. There is, however, a slight variation arising from the difference of weight of the holder according to the extent of its immersion, and another caused by the body of the beam, in proportion to its deviation from the horizontal. This error is neutralised by the action of a weight hanging from a cycloid fixed to the gudgeon of the beam. The greatest delicacy of action is further ensured by resting the gudgeon on friction wheels; so that, all things combined, governors of this description practically maintain the pressure to which they are adjusted, under variations on the inlet of from $\frac{5}{10}$ths to 6 inches.

But in all cases when, as in photometry, an unvarying rate of consumption is absolutely necessary, the pressure under the inlet of the balance governor should be tolerably uniform, and, to secure this, a common dry governor should be fixed before the meter, so that the pressure on the inlet of the meter should not exceed 8 or 10 tenths. This rough regulation of the pressure before the meter tends to more absolute certainty in the correctness of the quantity measured and supplied to the testing burner, and prevents overflow of water from sudden excess of pressure, which is not an unfrequent occurrence when the photometer is fixed upon an outlet main supplied by different gas-holders of various weights.

The direct regulation of the quantity admitted to the test burner is performed by means of a double cock (Fig. 6), the upper one being used to turn the gas completely on or off, while the lower one, which is fitted with a micrometer screw arrangement, enables the operator, by turning the milled-head, to make his adjustment with that delicacy and precision so necessary in conducting a careful experiment.*

BALANCE.

To ascertain the consumption of the candles and the consequent rate per hour at which they burn, a balance is required, which should be sufficiently sensitive to turn with the tenth of a grain when loaded. One of the scales should be a flat glass plate, and the other ought to be tolerably deep, so as to hold a small quantity of sparrow shot. It should be kept in a glass case, and frequently looked to, to keep it in order.

THE DISC.

The disc is made of the best white drawing paper, a circular spot being left opaque in the centre, and the external annulus rendered partially transparent by melted spermaceti. Considerable care is necessary in the preparation of these papers, so that the quantity of spermaceti may be perfectly uniform all over the surface. This is secured by a small machine contrived by the Editor, which effects its object admirably. There is also another kind of disc, which is generally supposed to have been first suggested by Dr. Leeson. It consists of three pieces of paper; a centre one made of cream-laid note paper, with a circular or star-shaped hole cut through it, about 1 inch in diameter, and two other pieces of white foreign post placed on each side of it. The advantage of this disc is its perfect uniformity of surface, and its being precisely the same colour on both sides; and in using it, instead of having to compare two slightly illuminated spots, as in the spermaceti disc, we only have to determine which disc presents the most distinctly-defined star, without reference to the colour of the surface. The only objection to be urged against the three thicknesses of paper, is the difficulty of securing perfect contact all over the surfaces.

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* The regulation of the consumption may also be made by means of small shot either added to, or abstracted from, the weight scale attached to the governor.

The method by which to adjust the disc during an experiment is as follows, viz.:—

Supposing one of the first-named or greased discs is in the photometer, the lights are equal when the opaque spot left in the centre is visible to the same extent on one side as on the other. If the lights are unequal, then the opaque spot will show brighter on the side of the stronger light, because that passing through the translucent portion of the disc, will cast the opposite side of the spot into shadow.

The effect on the Leeson disc is exactly the reverse, for the light falling on it makes the star appear darker on the side of the stronger light, and brighter on that towards the weaker. The lights are equal when the star is defined as clearly on one side as the other.

The merit of this kind of disc consists in the fact that the lights can be equalised irrespective of their colour. Thus the candle appears, by comparison with the gas, to illuminate the disc on its own side with a kind of brownish light, while that on the side of the gas appears whiter. Again, the colour of the light from a batwing under high pressure is whiter than that from the same kind of burner under low pressure.

These differences of colour affect in some degree the unpractised eye when the greased disc is employed, hence the superiority of the Leeson disc for the use of experimenters not in the constant practice of photometry, or for experiments where there is a wide distinction of colour between the lights to be compared.

BURNER.

The burner for common gas is described in the Metropolis Gas Act as "an argand burner, having 15 holes and a seven-inch chimney."

To this vague description may be ascribed an enormous amount of error and dissatisfaction, for although there is no doubt it was the intention of the Legislature to give the Companies the full benefit of the most suitable burner for displaying to the best advantage the quality of the gas they supplied, still it is quite possible to make a burner, complying literally with the words of the Act, which will exhibit the light of *two candles only*, from 14-candle gas consumed at the specified rate of 5 feet per hour. To obtain this, it is only necessary to make the holes somewhat smaller than usual, the diameter of the circle cutting the holes rather less than an inch, and the centre opening about five-eighths, and the effect just described is the result. Now it is quite evident that such a burner as this was never contemplated by Parliament. The opponents of Gas Companies, however, never fail to supply the omission with details of their own, and produce such a burner as will depreciate the quality of the gas it is professedly to test.

In some very recent Acts of Parliament, however, an attempt has been made to define with greater exactitude the proportions of the burner to be used as a standard; and in the case of "The Birmingham and Staffordshire Gas Act, 1864," it is described as "a metal argand burner, having an external diameter of 1·10 of an inch, and an internal diameter of 0·50 of an inch, and having fifteen holes, each hole of the diameter of 0·05 of an inch, and with a seven-inch chimney supported upon an ordinary gallery without a perforated disc."

Although this is a step in the right direction, the definition is still incomplete, for no mention is made either of the diameter of the chimney or the height of the burner from the glass holder to the top—two important points. Unfortunately, too, from want of an intimate knowledge of the subject, the Legislature has been induced to select a burner which is far from being suitable as a standard. The model was not made to suit the requirements of a testing burner at all, but a pattern not originally constructed for a 15-hole common gas burner was obtained and altered in some of its most objectionable features. With this, it is possible, when quite new and clean, to obtain an approximate value of the gas, supposing it to be not greater than 14 candles, but a more carefully designed burner would show it to be really eight-tenths of a candle superior, and for which, of course, the Birmingham and Staffordshire Gas Company would gain no credit. Besides, if the gas be more than 14 candles, it is very probable, when tested by the standard, to be recorded as less than 14, because, if the rate of consumption be maintained at 5 feet per hour, the burner will smoke, and, consequently, give less light. To obviate this, the tester is compelled to neglect this regulation in the Act, reduce the consumption, and increase the illuminating power as read off from the photometer to the standard of 5 feet, by a rule of three calculation. This is a source of error that is increased as the rate of consumption is reduced, because the decrease of light per tenth of a foot of gas is much greater than the proportion found by the rule of three. The very exhaustive series of experiments made by Messrs. Audouin and Berard of Paris, and which are translated into English, satisfactorily set this question at rest; but, as we have a standard before us which is likely, if followed by future legislators, to lead to much litigation, it will perhaps be as well, as a dissuasive against its further adoption, to give a few specimens of the results obtained by it, in comparison with the burner used by Dr. Letheby for testing the gas supplied to the city of London. (Pl. 10.)

Quality of gas as exhibited by Dr. Letheby's burner.

	Candles burning 120 grs. per hour.
5 feet per hour	15·5

Quality of gas as shown by the Birmingham standard burner.

	Candles burning 120 grs. per hour.	
5 feet per hour	14·00	Results corrected to the standard quantity of gas by proportion.
4·9 " "	13·78	
4·8 " "	13·74	
4·7 " "	13·30	
4·6 " "	13·04	
4·5 " "	11·93	

The foregoing demonstrate two facts—firstly, that the Birmingham burner, even when burning the full quantity of 5 feet per hour, does not show the true quality of the gas; and, secondly, the inapplicability of the rule of three for estimating the light given in proportion to the quantity consumed, otherwise the whole of the results would have been 14 candles.

If, however, the candles had been also burning at a rate proportionately less than 120 grains per hour, the error would have been neutralized, thus:—

120 grs.	. . 5·0 cubic feet	=	14 candles.
118 ,,	. . 4·9 ,,	=	14 ,,
115·5 ,,	. . 4·8 ,,	=	14 ,,
113·0 ,,	. . 4·7 ,,	=	14 ,,
111·5 ,,	. . 4·6 ,,	=	14 ,,
109·0 ,,	. . 4·5 ,,	=	14 ,,

But, on the other hand, if the candles had been burning *more* than 120 grains per hour, and the gas richer in quality, the error would have been greater, as will be seen from the following table:—

	124·5 grs.	. 5·0 cubic feet,	15·48 candles.	Burner smoking.
Candles slightly smoky.	129·0 ,,	. 4·7 ,,	16·12 ,,	
Candles smoking.	138·0 ,,	. 4·5 ,,	17·70 ,,	

Now, it may be urged that, according to the Act of Parliament, an official tester is bound only to record such experiments as are made at a time when the candle is burning 120 grains per hour; but as the Act does not compel him to state in his reports the rate at which the candle was consumed at the time he made his observation of the illuminating power of the gas he reports upon, and as the exact consumption of 120 grains is a phenomenon which an experimenter does not very often see—that is, if the candle be allowed to burn in its normal condition—it is very probable that, unless he does correct for error by some rule, he stands a very good chance of making no report at all, at least within the time he is required to do so. Under these circumstances it must be admitted that the sources of error are numerous enough; and although those due to the candle would occur with any other burner, yet there is no reason why, as in the case of the Birmingham standard, the chances of error should be multiplied by compelling the tester to deviate from the specified quantity of 5 feet.

The imperfections in the Birmingham standard arise from the width and shape of the top, which, being both flat and wide, create such currents in the flame, that the particles of carbon are diverted from their true upward course and made to eddy over the top between the holes, till they are either destroyed or deposited, in the latter case raising small mounds of carbon between the holes, and heating the burner all over to a pernicious degree. Another very objectionable feature is, that the top is made of a material, which, if not frequently cleansed, affects, by its corrosion, the size of the holes; while, if care be taken to remove the accumulated oxydation or deposit of carbon, a hard tool must be used, which soon destroys their uniform size, and of course, when once this is done, the burner ceases to be a standard within the meaning of the Act.

The burner most generally in use as a standard for gas testing, throughout England and the colonies, is that known as "Sugg's burner." (Pl. 10, Figs. 1 and 2.) This burner, the top of which is formed of steatite, is a 15-hole Argand, with a 7-inch chimney, and made of the dimensions shown on the Plate, which are full size drawings of plan and section; the first being intended for gas of about 12 candles, and the second for 14 candles. It will be noticed that the gallery for these burners, Fig. 5, is filled in at the bottom with perforated metal.

Much discussion has occasionally arisen concerning the purpose for which the disc has been introduced. Its real object is, however, simply to check in some degree the amount of air admitted to the outside of the flame, and to distribute the air so admitted equally to every part of the ring. Gas of the exact illuminating power for which the burner is made and marked, is slightly depreciated rather than increased by its presence, but if, when the gas is better than that marked on the burner, and is burning at the rate of 5 feet per hour, the flame tails over the glass, or looks smoky at its top, then the disc becomes useful by checking the draught to the outside of the flame, which would otherwise be elongated and thrown together at the top. The use of the disc tends also to increase the current up the centre, and these two circumstances combined, that is, the decrease of the external and increase of the internal currents of air, conduce to a more perfect combustion of the richer gas.

The disc then is only used to assist the tester in representing justly the illuminating power, so that if the gas supplied to the public be better than the standard prescribed by Act of Parliament or agreement, it may be so recorded by the official tester, in the same manner as it would undoubtedly be if it were below the standard.

It has been contended, that, if it is necessary to have different burners to test different qualities of gas, such burners are unsuited for consumers, and that therefore the value given to the gas by them is fictitious. A very little explanation will show the fallacy of this doctrine, and at the same time strengthen the argument, that the full value of the gas should be noted whenever it exceeds the quality directed by law.

All Acts relating to the testing of gas distinctly state, that the gas shall be consumed at a stipulated rate, and shall equal a given number of candles. Now, if the gas is much richer than that required by the Act, and no proper provision made for recording its true value, it is, as shown in preceding experiments, very likely that a much less value may be given to it than it really possesses. Nevertheless, the consumer reaps the advantage of the increase in quality, because he is not bound to consume a specified quantity per hour, but requires only to obtain from each burner a certain amount of light, so that he gets with a smaller consumption the full quantity of light prescribed by the Act, and thus economizes his gas by reason of its superior quality.

A much better test burner, however, than any hitherto exhibited may be formed by simply inverting the top of the burner, as shown in Fig. 8, and drilling the holes nearly through on one side, and on the other cutting a circular slit or channel, so that it shall intersect all the holes. By this means, the column of flame would be exactly the same in thickness all round, and the air would take equal effect upon all parts of the flame; so that by merely diminishing the width and enlarging the diameter of the slit, burners might be made to suit any quality of gas up to 20 candles, without, at the same time, causing too great a difference in their measurements. The superiority of burners of this description is that they would justly represent the value of gases varying from two to two and a half candles.

Pl. 11, (Figs. 1 and 2), are full-sized drawings of one of these burners.

The best standard burner for testing gas is, at the same time, the best burner for the consumer, as the principles to be observed in the construction of both are identical, and may be stated thus:—

That the quantity per hour of gas it is made to consume shall be permitted to arrive at the point of ignition by an easy and regular flow, without eddies, and at such a velocity, that after passing through the holes or other aperture in the top, the particles of carbon contained in the gas shall not be driven out at the top of the chimney, until the oxygen of the atmosphere has had time to raise them to a sufficiently high state of incandescence, both to render them luminous to the fullest degree, and thoroughly consume them.

That the quantity of air for the proper combustion shall be so regulated, that every portion of the flame shall receive a steady and uniform supply sufficient to support the combustion of the gas, but not in excess;* so that, on the one hand, the flame may not fork and give off unconsumed carbon, or, on the other, destroy the particles so rapidly as to evolve heat without light (like a Bunsen burner).

That the top shall be unalterable by the action of heat or corrosion, so that the burner may be at all times in the same condition for the purposes of lighting, as at the time it was made.

Any burner which does not fulfil these requirements, is unfit for both the official tester of gas and the consumer; and here it will not be out of place to remark, that an argand burner, for the economical burning of gas, requires its regulating apparatus for the admission of air, as much as an argand burner for burning oil, more especially, when the gas to be consumed is rich in carbon; and therefore any attempt to properly consume gas, with advantage to the consumer and credit to the manufacturer, by means of

---

* As a parallel example of the effect of air in excess, it may be mentioned, that if the current of oxygen in the oxyhydrogen lime light be unduly increased, the luminosity of the particles of lime may materially be redneed, the well-known brilliant white light being only evolved with a proper proportion of the gas.

Sugg's pattern for 12 candle gas—Mark 12c.

	Inches.
External diameter	1·10 across top.
Centre aperture	0·44.
Diameter of holes	0·06.

Diameter of chimney, 1⅞ inside.

Steatite top—15 holes—perforated regulator for air (*see* Plate 10).

Sugg's Dr. "Letheby's model" for 14 candle gas—Mark 14c.

	Inches.
External diameter	1·10 across top.
Centre aperture	0·48.
Diameter of holes	0·06.

Diameter of chimney, 1⅞ inside.

Steatite top—15 holes—perforated regulator for air (*see* Plate 10).

These two last-mentioned burners are generally in use for testing common gas throughout the principal towns of England and Ireland, in Australia, Calcutta, Bombay, Singapore, China, and in several cities in North and South America.

Sugg's "Imperial" model for 14 candle gas—Mark 14c.

	Inches.
External diameter	1·10 across top.
Centre aperture	0·50.
Diameter of holes	0·06.

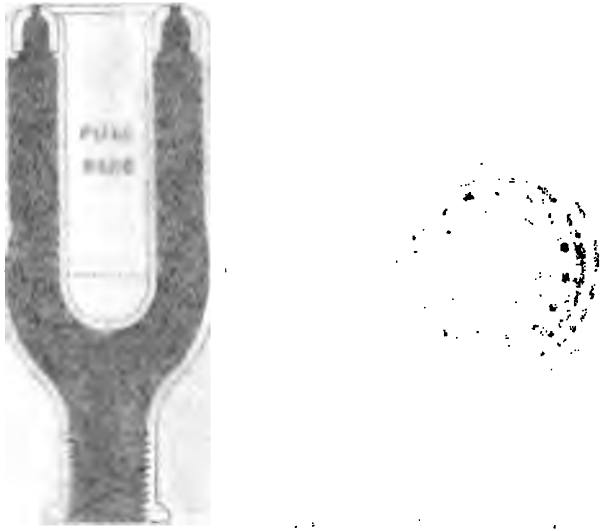
Diameter of chimney, 1⅞ inside.

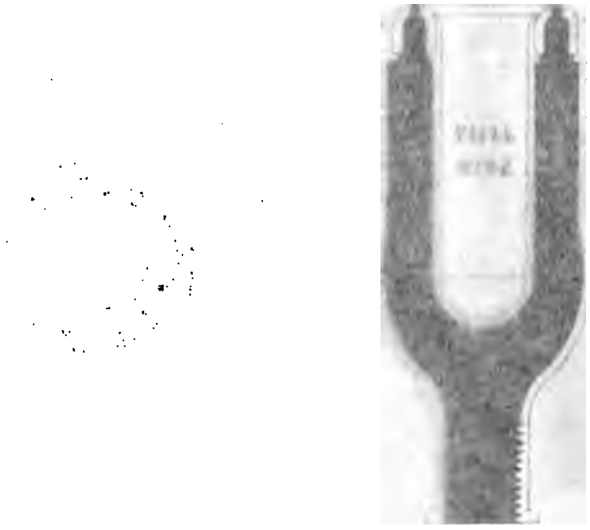
Steatite top—15 holes—perforated regulator for air.

Proposed by the parish of Marylebone for testing the gas to be supplied by the Imperial Gas Light Company.

12 [illegible]

[illegible]





Sugg's " Dublin "—for 16 candle gas—Mark 16c.

		Inches.
External diameter	. .	**1·10** across top.
Centre aperture	. .	**0·55.**
Diameter of holes	. .	**0·06.**

Diameter of chimney, 1⅞ inside.

Steatite top—15 holes—perforated regulator for air.

In use for testing gas at Dublin.

For testing 18 candle gas the number of holes should be increased, because the diameter of the circle cutting the centre of the holes is so large that they are consequently placed too wide apart.

Sugg's " New Model " for 18 candle gas—Mark 18c.

		Inches.
External diameter	. .	**1·15** across top.
Centre aperture	. .	**0·60.**
Diameter of race	. .	**0·01.**

Diameter of chimney, 1⅞ inside.

Diameter across outside of race, 0·90.

Steatite top—circular race—perforated regulator for air.

Proposed model for standard burner (*see* Plate 11).

THE STANDARD CANDLE.

Next in order comes the standard sperm candle, which unfortunately is little better than the standard burner. All existing Acts of Parliament define it as a " sperm candle of 6 to the pound, burning at the rate of 120 grains per hour."

A true sperm candle is made from a mixture of refined sperm oil with a small proportion of wax sufficient, in technical language, to " break the grain," that is, to give it a certain toughness—the pure sperm itself being extremely brittle.

The wick is of best cotton, made up into 3 cords and plaited. The number of strands in each of the 3 cords composing the wick of a 6 to the pound candle is 17, although there does not appear to be any fixed rule, some candles having more and others less, according to the quality of the sperm.

Sperm candles are made to burn at the rate of one inch per hour, and, in burning, the outside of the candle ought to melt last, so that round the wick there should always be a well shaped cup, about one-eighth of an inch deep, clean, smooth and dry, Pl. 11, (Fig. 3).

The wick should be curved slightly at the top, the red nose or tip just showing through the flame, and consuming away without requiring snuffing or attention.

To obtain these results the tightness of the plaiting and size of the wick require careful and constant attention, and, as the quality of the material differs in richness or hardness, so must the plaiting and number of strands.

Hence, it appears, arises the difference in these two items, which, although not important to a consumer of candles, will be found to exercise a material influence upon the sperm candle as a standard for the illuminating power of coal gas.

Sperm oil itself differs in quality according to the part of the whale from which the blubber has been extracted, that from the head producing the finest oil. The sperm is prepared by the oil refiners, and sold to the candle maker in large oblong blocks, about 3 feet long, 1 foot 3 inches wide, and 6 inches thick; consequently he is entirely ignorant of its composition excepting so far as he can judge by its appearance and working.

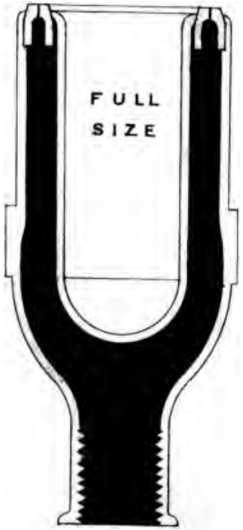
Here, therefore, is a variety of possible combinations, all of which affect the illuminating power of a standard sperm candle.

Pl 11

PROPOSED NEW BURNER

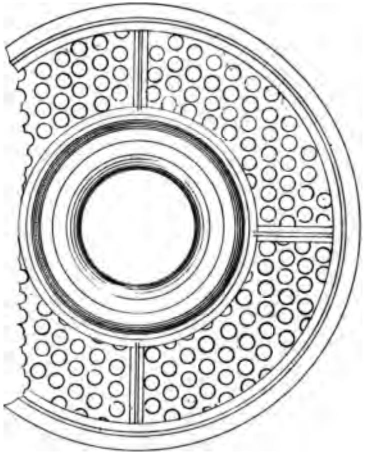
18 Candle Gas (Sugg)

Fig. 1



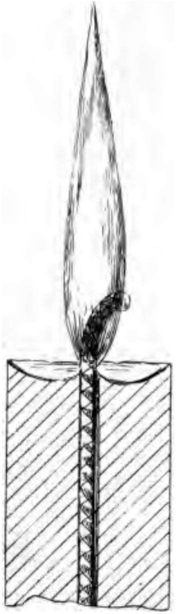
Section of Burner

Fig. 2



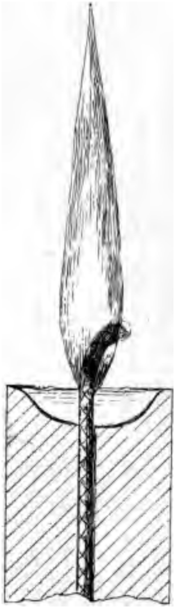
Plan of Glassholder & Burner Top

Fig. 3



SPERM

Fig. 4



PARAFFIN

Entd at Stationers Hall

W Blanchard & Sons 62 Millbank St Westminster.

These difficulties are small, compared with those which have resulted from the introduction of paraffin and petroleum, for, from these oils a solid material is prepared, which, though inferior to sperm in many points, is yet superior to it in illuminating power, and it is incontestable that candles can be made with such combinations of stearine, wax or sperm, and petroleum, as to possess all the characteristics of sperm candles, and yet be superior in illuminating power, while, on the other hand, the same materials, otherwise combined, are inferior.

Here again the wicks vary, for, as a rule, these candles require wicks more tightly plaited and with fewer strands than those suitable for the true sperm candle.

In France, the standard is colza oil, burned, at a given rate, in a carcel lamp, of accurately defined dimensions. This, although inaccurate from the variations in the quality of the oil, according to the locality in which the rape is grown, is yet free from many of the sources of error inseparable from the English standard.

Assuming, however, for the purposes of this work, that good average sperm candles may at all times be obtained, it will be well now to point out the best way of working with them, so as to arrive at results as nearly the truth as possible under existing circumstances, showing, by the results of careful experiments, the errors which are possible, with a view to put the reader on his guard against them. At the same time it must not be supposed that the experiments quoted are exaggerated for the sake of example, for an examination of them will show that they may easily be of every-day occurrence.

The candles to be used as standards must be kept in a cool place, and covered up from the dust and air till they are wanted for use. They should also be very hard, and rattle when shaken together.

New sperm candles cannot be depended upon to burn well or give true results. From a number of experiments made with sperm candles it appears that, with the method of conducting experiments now adopted, there is an error whenever the consumption of the candle is above or below the prescribed 120 grains per hour, larger or smaller, according to circumstances such as the following:—

If the candle is hard, and has been kept in a cool place, the particles of carbon contained in the material to be consumed detach themselves slowly from the mass and allow the wick time to burn off short, so that, being properly supplied with sufficient air for perfect combustion, each grain of sperm consumed contributes its full quota to the illuminating power of the whole, which is then at its maximum. But if the candle has been kept in too cold a place, and the room in which the experiment is performed is also cold, then the particles are too slowly detached, and receive too much air, resulting in the production of a minimum amount of light from the entire consumption.

Similar effects to both of these are produced by differences in the size and plaiting of the wicks.

If, on the other hand, the candles have been kept in a warm place, and used in a warm room, the result is diametrically opposite. Like effects are produced by dirt accumulated round the candle, which, being drawn into the wick while burning, cakes on it; as well as by loosely plaited and large wicks.

The endeavour to correct variations from the standard consumption, and to assimilate results obtained by defective candles to those obtained by good ones consuming exactly 120 grains per hour, in the usual manner by proportion, conducts no nearer to the truth, but rather the reverse.

The following experiments made upon the same gas, supplied from a 5-feet gasholder, and burned in the same burner, regulated to an unvarying rate of consumption, will serve as illustrations, premising that the results were corrected to the Parliamentary standard in the usual manner.

50-inch Photometer.

Two candles, consuming at the rate of 123·9 grs. per hour.	Birmingham standard burner, consuming at the rate of 5 cubic feet of gas per hour.

Average of 10 readings of photometer scale . 12·03 candles.

Illuminating power of gas, corrected to Parliamentary standard . . . } **12·40 CANDLES.**

2nd Experiment.

Different pair of candles consuming at the rate of 132·9 grs. per hour.	Birmingham burner as before.

Average of 10 readings of photometer scale . 12·40 candles.

Illuminating power of gas, corrected to Parliamentary standard . . . } **13·85 CANDLES.**

A comparison of the working of the two experiments will clearly show the cause of the disparity in the results, which is 1·45 candles.

The average of the readings of the photometer in the first experiment is 12·03 candles for a consumption of 123·9 grains of sperm per candle per hour; and in the second, 12·40 candles for a consumption of 132·9 grains per candle per hour: thus, 9·0 grains increase of sperm per candle per hour gave a total increase of ·37 of a candle, or 9·0 × 12·40 = 111·6 grains of sperm = ·37 of a candle.

Now, if these 111·6 grains had been consumed with an independent wick, it is evident they would have produced a light not very far short of a candle consuming 120 grains per hour. It is, therefore, certain that they must have passed off unconsumed, which was really the case, for the candles smoked, the wick being rather loosely plaited.

Now, the higher rate of consumption giving nearly the same illuminating power as the lower, it is evident that no correction ought to be made; but as under ordinary circumstances it is impossible to know whether the full illuminating power is obtained for the quantity of sperm consumed, correction must be made in the usual manner; accordingly, if the foregoing experiments had been performed by different operators, the unsatisfactory results above quoted must have been obtained.

The second experiment was thus in favour of the gas; but a third experiment, made immediately after it, with another pair of candles, all other circumstances remaining the same, gave a very different result.

3rd Experiment.

Two candles burning at the rate of 100·5 grains per hour.	Birmingham burner, as before, burning 5 ft. per hour.

Average of readings of photometer scale .	13·42 candles.
Illuminating power of gas, corrected to Parliamentary standard . .	**11·2 CANDLES.**

The difference between the corrected result obtained with the pair of candles nearest the standard (1st exp., 123·9 grains per hour) and that obtained with the last pair is—

1st experiment .	12·40	candles.	
3rd „ .	11·20	„	
	1·20	„	Difference, 10·33 per cent.

Analyzing the experiment, we find a difference in the consumption of sperm between the 1st and 3rd experiments of 23·90 grains per candle per hour, whilst the difference in illuminating power, as shown by the average readings, is 0·59 of a candle. The average readings are—

1st experiment .	12·03 candles.	123·9 grs.	per hour.
3rd „ .	13·42 „	100·5	„

The deduction for the lesser quantity of sperm consumed in the 3rd experiment should be practically 0·59 of a candle; thus, 13·42—0·59=12·83 candles. Now, referring to the 1st experiment, the result, corrected to the standard, is 12·40; making allowance for the possible error, and regard being paid to the fact that the pair of candles there employed consumed not 120 grains, but 123·9 grains per hour, the real value of the gas would doubtless have been, with standard candles burning 120 grains per hour, 12·50 candles.

The correction of this last experiment by proportion is therefore an error.

It will thus be seen from what has been said how important it is that in all experiments for estimating the illuminating power of gas the candles made use of as standards should be well made, of good material, and be consumed as nearly as possible at the rate of 120 grains per hour; and that all experiments with guttering or smoky candles, or with candles burning below the standard number of grains, should be considered unreliable—for it must be remembered, that every error in the standard being multiplied by the number of candles the gas is equal to, it follows that the better the quality of the gas the more the errors will tell; and as the tendency of legislation at present seems to be towards raising the standard of illuminating power, greater care than ever will have to be taken to avoid them. With regard to the question which has frequently been raised by experimenters, as to whether it makes any difference in the illuminating power per grain of sperm consumed, if the candles are allowed to burn in their normal state or snuffed, it appears from some experiments made with candles both snuffed and unsnuffed, that when burning at a high rate of consumption, and smoking, snuffing the wick just before they come into balance on the scale, is advantageous generally to the experiment, while, on the other hand, if done with candles burning at a lower rate, the reverse is the case. It is, however, obvious, from the preceding remarks, that any interference with the natural burning of the candles must be very carefully done to be successful. Having then enumerated the most probable sources of error, it now remains to state a method upon which it is possible, under the present parliamentary regulations, to arrive at the truest result, premising that, considering the errors which may arise with *bonâ fide* experimenters not aware of the facts before stated, any results of observations upon the illuminating power of gas, unaccompanied with the full particulars of the conduct of the experiment, ought to be accepted with caution, if at all.

FIXING THE PHOTOMETRICAL APPARATUS, EVANS' SYSTEM.

The room should not be less than 12 feet by 10 feet, well ventilated and free from draught, warmed by a stove or other method, and kept dry.

The ceiling may be white and the walls papered. An office is, perhaps, the best possible photometer room which can be chosen, because it is generally in use, dry and warm.

It is immaterial whether the photometer is fixed in the centre of the room or against the wall, although preference would be given to the wall, because the bench or other arrangement to receive the apparatus may be more firmly fixed there. If the room has many windows, coloured blinds of dark blue, green or purple, may be fixed to each window, in order to diminish the glare of daylight during the performance of experiments; these blinds may be fixed outside the ordinary white or other blinds, only to be made use of with the photometer.

At the same time, it is proper to observe, that the instrument does not necessarily require these adjuncts, being provided with a screen, but some experimenters prefer to check the daylight coming into the room; doubtless, if the experimenter stands in a dull light, he is able to appreciate finer gradations of shadow, yet, a little practice and the use of a good disc, will enable any person to obtain good observations with these instruments even in sunlight. Notwithstanding, when the instrument is to be employed for the purpose of testing gas for the public, it ought to be provided with every appliance calculated to aid the official tester in his experiments, because, not being generally in the constant practice of making them, he does not possess that readiness of vision which is obtained by those making daily tests.

A testing gas-holder to contain 5 cubic feet of gas would be of great service, because when the pressure is as low as five-tenths in the main, it becomes difficult to get a good test with any other burner except an argand, but a gas-holder ensures always a sufficient and uniform pressure. When this does not form part of a photometrical apparatus, its place must be supplied by a governor (dry or wet), regulated to one-inch pressure upon its outlet, otherwise an increase or decrease of pressure will interfere with the consumption of the burner, more especially when the photometer is being supplied direct from the station gas-holders.

In all cases, where the photometer is supplied from the inlet of station meter, and the pressure is high, a double governor is best.

A strong deal bench, 12 feet long and 2 feet wide, will hold the photometer and all its apparatus; the instrument itself being provided with standards to raise it sufficiently high from the bench, that the meter, governor, pressure gauge, and scales, can all be fixed under it. The height of the bench must be regulated by the opinion of the person who is going to use it, but, as a general rule, 3 feet is suitable for a person of middle height, *i. e.*, the "sighting glass" will be about the level of his eyes.

Another method of arranging these instruments is, to fix the photometer against the wall by means of light ornamental cast-iron brackets, and to group all the rest of the apparatus on a strong table or, still better, a shelf, secured to the wall—placing the pressure gauge over the meter and governors, which are at the back of the table, the front being used for weighing the candles and writing.

Over the table, a small bracket may be fixed, with a copper consumer over it, of such a form that the inside may, whitened with common whiting, reflect the light down on the table without permitting the rays from the burner to illuminate the rest of the room. In all cases, however, care must be taken that the table, upon which the meter and governor are placed, cannot be shaken, either by walking about the room, or in any other way, else it will be difficult to keep the rate of consumption uniform.

An ordinary pressure gauge is required to show the pressure on the main.

A barometer and thermometer should also be included with the apparatus, and the state of the barometer and the temperature of the room should be noted at the time the experiment is performed.

DIRECTIONS FOR ASCERTAINING THE VALUE OF THE ILLUMINATING POWER OF COAL GAS, IN STANDARD SPERM CANDLES, BY MEANS OF THE PHOTOMETER.

F. J. EVANS' SYSTEM.

Select a 15-hole steatite-top argand burner, which will consume 5 cubic feet of gas per hour without over oxydizing the flame, or smoking, and which does not require more pressure than four to five-hundredths of an inch of water at the point of ignition to make it pass gas at that rate, fitted with a chimney of thin clear glass, of the height of 7 inches, and 1⅞ inches across the inside, the glass holder being covered at the bottom with perforated brass of the size shown in plates 10 and 11.

Four-hundredths of an inch is the pressure most suitable for 12 candle gas; but for 16 candles, a pressure of five-hundredths is better.

Let it burn for a sufficient time before commencing an experiment, to ensure that all the air or dead gas is thoroughly expelled from the apparatus.

Light two candles, and after seeing that the rims of the cups round their wicks are level, leave them till they have arrived at their normal state of burning, *i. e.*, the wick just turned at the top and burning off.

If the rims of the cups are not at first level, the candles, after being lighted, may be slightly inverted and turned round, until the tops are melted even, after which, they can be returned to their holders, and left to get into burning order.

Adjust the consumption of gas to 5 cubic feet per hour.

> This is done in the manner pointed out in the description of the clock meter (page [illegible]).

When the gas and clock hands of the meter will travel together continuously, stop the clock, and pull back the 10-minute hand to zero.

Place the two candles with their candle holder into the scale, carefully, without extinguishing them. If they are in burning order, balance the contra scale by means of some small shot, leaving the candle side slightly the heavier. Place a small piece of wood under this side, so that the pointer of the scales may be exactly on the balance point, or upright. Then place one finger on the starting lever of the clock, and at the moment the scale turns, start the clock.

Record the position of the gas-hand at the moment of starting the clock, also the hands of the small dials on the right and left of the centre.

> This can easily be done by looking first at the gas hand; there will be plenty of time to take the position of the others.

Carefully place the candles in the photometer.

Shut down the doors and shift the candles gently, by means of the handle, till both sides of the disc are equally illuminated—*i.e.*, when the spot of the greased or star of the Leeson disc can be seen as well upon one side as the other.

As the bell strikes for the first minute, record the reading of the photometer scale.

> If there should not have been time to do all these things in one minute, mark down the observation as soon as it is made; but upon no account hurry, nor record it till perfectly satisfied of the equality of the lights, for if the candles are good and have been properly prepared, the difference in the illuminating power during ten minutes will be so small as not to create appreciable error, although two observations were recorded at the same time.

In like manner record observations every minute for 9 minutes, recording the tenth observation on the 9¾ minute.

Have the door opened, and as the tenth minute strikes, blow out the candles and record the position of the gas hands and left-hand time hand; then record the state of the index.

> It is well to have a piece of sperm always in the candle pan at the time of weighing, which may be used, when the candles are blown out, to

extinguish the red snuff of the wick, by which means smouldering is prevented and the wick left in a better state for relighting for the next experiment.

If the gas hand has gained upon the time hand, the quantity supplied to the burner must have been in excess, and *vice versâ.*

The number of tenths of a foot they have separated from each other must be divided by 10, and the quotient deducted from or added to the standard rate of consumption.

If the rates of the consumption of the gas and candle have been respectively 5 cubic feet and 120 grains per hour, the mean of the readings of the photometer will be the correct value of the gas in terms of the standard candle.

If otherwise, proportionate corrections must be made.

In this experiment the gas was found to be equal to 12·91 candles, burning at the rate of 123·0 grains per hour.

Now, therefore, it is certain that it must have been equal to more than 12·91 candles burning at the rate of 120 grains per hour, consequently we have the following simple proportion:—

As 120 : 123·0 : : 12·90 : 13·23,

. the illuminating power of the gas was then 13·23 candles.

When the rate of the gas per hour is greater or less than 5 cubic feet, correction is made in the following manner:—

Rule.—Multiply the corrected value of the gas in terms of the standard candle by the standard rate per hour, in cubic feet, and divide by the actual rate at which it has been consumed.

Example.

	Rate at which the gas has been consumed.				Ill. power of gas in terms of the standard candle.		Result corrected to both standards.
As	5·2	:	5	: :	13·54	:	13·02.

It will be readily seen, from an inspection of the above formula, that a decimal fraction can be found which will perform these two operations at once; and a general table, calculated by the Editor upon this principle, is given on page 83. As an example, let it be supposed that 5·4 cubic feet of gas per hour has been found to be equal to 14 candles burning at the rate of 123 grains per hour. Consulting the rule at the bottom of this table, there is found under the column 123, and on the line 5·4, the fraction ·94907.

Multiplying the mean of the readings of the photometer by this fraction,

$$14{\cdot}000 \times {\cdot}949 = 13{\cdot}286.$$

The standard value of the gas is, therefore, **13·29 CANDLES.**

Still further to simplify these experiments and ensure accuracy, the author of these tables has calculated from it a set by means of which the corrected value of any gas, from 10 to 40 candles, can be found by inspection. The advantage to be derived from the use of tables is principally to be found in the certainty of the results being correct if correctly copied.

Upon Plate 12 will be found a lithographed form for photometrical experiments, published by the Editor, in books containing 150, to be filled up in the manner shown. Each form has a stump end, so that the results may be copied upon that, and the form itself forwarded to the proper officer appointed to receive it.

Pl. 16

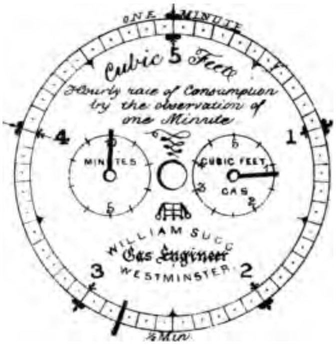
Example

Photometrical Experiment.

Date Jan 3rd 1867

Parliamentary Standard Argand Burner
Letheby 14 C compared with
Two Sperm Candles of 6 to the lb.

Position of Gas & Clock hands



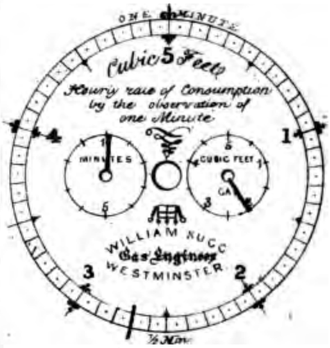
at commencement of Experiment.

Readings of PHOTOMETER.			
1st minute	6	3	5
2nd "	6	3	0
3rd "	6	3	0
4th "	6	4	0
5th "	6	4	5
6th "	6	5	5
7th "	6	5	0
8th "	6	5	5
9th "	6	5	5
last "	6	6	0

10/645 ~~5~~

64 5

Position of Gas & Clock hands



at End of Experiment.

Barometer 29.4 mean of $\frac{12.9\,0}{2}$ Readings. Temp. 65°

Consumption of Sperm by 2 Candles } 2 | 41.0 grs. / 20.5 = 123.0 grs. per hour. see Ta

Consumption of Gas, Rate per hour } 5.0 Cub. feet

Pressure at point of ignition 0.45 in.

Ill. power corrected to the Standard of 5 feet per hour and 120 grs. } 13.22 Candles. see Tab

(Signed) ....

nt.^{d} at Stationers Hall

W^m Blanchard & Son, 62 Millbank S^t Westminster.

Example.

Jan. 3rd, 1867.

Common Gas, tested by the "Letheby" 14 c. burner— Rate, 5 feet per hour.

* * *

1st Minute	.	6·35
2nd ,,	.	6·30
3rd ,,	.	6·30
4th ,,	.	6·40
5th ,,	.	6·45
6th ,,	.	6·55
7th ,,	.	6·50
8th ,,	.	6·55
9th ,,	.	6·55
10th ,,	.	6·60

10) 64·55

6·45

2

12·90

Consumpt of 2 Candles.

41·0

6·0

2) 246·0

123·0 grs.

Press at point of ignition, 0·45 in.; Temp., 65 degrees Fahr.; Bar., 29·4.

Result—5 ft. Gas = 12·91 Candles at 123·0 grs. per hour.

123·00

12·90

11070·0

24600

12300

12·0) 158·67300

13·22

Result, corrected to standard—5·0 ft. = 13·23 candles.

Example.

Jan. 3rd, 1867.

Common Gas, tested by the "Letheby" 14 c. burner—Rate, 5 feet per hour.

1st Minute	.	6·35
2nd ,,	.	6·30
3rd ,,	.	6·30
4th ,,	.	6·40
5th ,,	.	6·45
6th ,,	.	6·55
7th ,,	.	6·50
8th ,,	.	6·55
9th ,,	.	6·55
10th ,,	.	6·60

10) 64·55

6·45

2

12·90

Consumpt of 2 Candles.

41·0

6·0

2) 246·0

123·0 grs.

Press at point of ignition, 0·45 in.; Temp., 65 degrees Fahr.; Bar., 29·4.

Result—5 ft. Gas = 12·91 Candles at 123·0 grs. per hour.

123·00

12·90

11070·0

24600

12300

12·0) 158·67300

13·22

Result, corrected to standard—5·0 ft. = 13·23 candles.

SUGG'S PHOTOMETRICAL TABLE.

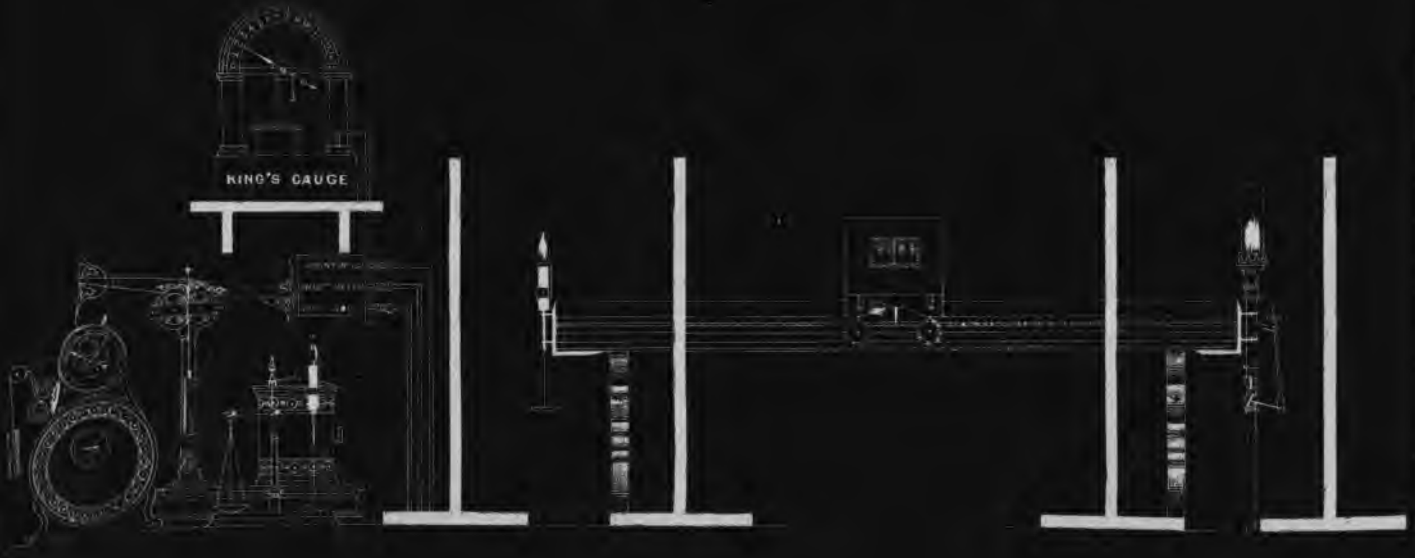
GENERAL TABLE, CALCULATED FOR ONE CANDLE.

Consumption of Gas.	GRAINS PER HOUR CONSUMED BY THE SPERM CANDLE.												
Feet per hour.	110	111	112	113	114	115	116	117	118	119	120	121	122
4·5	1·01851	1·02777	1·03703	1·04629	1·05555	1·06481	1·07407	1·08333	1·09259	1·10185	1·11111	1·12037	1·12962
4·6	·99637	1·00543	1·01449	1·02355	1·03260	1·04166	1·05072	1·05978	1·06884	1·07789	1·08695	1·09601	1·10507
4·7	·97517	·98404	·99290	1·00177	1·01063	1·01950	1·02836	1·03723	1·04609	1·05496	1·06383	1·07269	1·08156
4·8	·95486	·96354	·97222	·98090	·98958	·99826	1·00694	1·01562	1·02430	1·03298	1·04166	1·05034	1·05902
4·9	·93537	·94387	·95238	·96088	·96938	·97789	·98639	·99489	1·00340	1·01190	1·02040	1·02891	1·03741
5·0	·91666	·92500	·93333	·94166	·95000	·95833	·96666	·97499	·98333	·99166	1·00000	1·00833	1·01666
5·1	·89869	·90686	·91503	·92320	·93137	·93954	·94771	·95588	·96405	·97222	·98039	·98856	·99673
5·2	·88141	·88942	·89743	·90544	·91346	·92147	·92948	·93750	·94551	·95352	·96153	·96955	·97756
5·3	·86477	·87264	·88050	·88836	·89622	·90408	·91194	·91981	·92767	·93553	·94339	·95125	·95911
5·4	·84876	·85648	·86419	·87191	·87962	·88734	·89506	·90277	·91049	·91820	·92592	·93364	·94135
5·5	·83333	·84090	·84848	·85606	·86363	·87121	·87878	·88636	·89393	·90151	·90909	·91666	·92424

	GRAINS PER HOUR CONSUMED BY THE SPERM CANDLE.												
	123	124	125	126	127	128	129	130	131	132	133	134	135
4·5	1·13888	1·14814	1·15740	1·16666	1·17592	1·18518	1·19444	1·20370	1·21296	1·22222	1·23148	1·24074	1·25000
4·6	1·11413	1·12318	1·13224	1·14130	1·15036	1·15942	1·16847	1·17753	1·18659	1·19565	1·20471	1·21376	1·22282
4·7	1·09042	1·09929	1·10815	1·11702	1·12588	1·13475	1·14361	1·15248	1·16134	1·17021	1·17907	1·18794	1·19680
4·8	1·06770	1·07638	1·08506	1·09375	1·10243	1·11111	1·11979	1·12847	1·13715	1·14583	1·15451	1·16319	1·17187
4·9	1·04591	1·05442	1·06292	1·07142	1·07993	1·08843	1·09693	1·10544	1·11394	1·12244	1·13095	1·13945	1·14795
5·0	1·02499	1·03333	1·04166	1·04999	1·05832	1·06666	1·07500	1·08333	1·09166	1·10000	1·10833	1·11666	1·12500
5·1	1·00490	1·01307	1·02124	1·02941	1·03758	1·04575	1·05392	1·06209	1·07026	1·07843	1·08660	1·09477	1·10294
5·2	·98557	·99358	1·00160	1·00961	1·01762	1·02564	1·03365	1·04166	1·04967	1·05769	1·06570	1·07371	1·08173
5·3	·96698	·97484	·98270	·99056	·99842	1·00628	1·01415	1·02201	1·02987	1·03773	1·04559	1·05345	1·06132
5·4	·94907	·95679	·96450	·97222	·97993	·98765	·99537	1·00308	1·01080	1·01851	1·02623	1·03395	1·04166
5·5	·93181	·93939	·94696	·95454	·96212	·96969	·97727	·98484	·99242	1·00000	1·00757	1·01515	1·02272

Rule.—Multiply the number standing beneath the number of grains consumed by the Candle and opposite the number of feet consumed by the Gas burner, by the illuminating power as read off from the scale of the Photometer—the product is the correct value of the Gas reduced to the standard of 120 grains per hour and 5 cubic feet per hour.

PHOTOMETER _ D^{R} LETHEBY'S SYSTEM



attached and detached, without in the least deranging them whilst burning, or they can be weighed without disturbing them.

On the bar is a saddle-piece, running upon four rollers, carrying a "*Sighting Box*," which is a small chamber made of slight mahogany, divided in the middle by a metal plate, perforated in the centre with a hole about 3½ inches diameter, fitted with two brass rings, between which is held the disc of one of the kinds as described in page 61 ; at the back of the plate are fixed two mirrors, in a right-angled frame, so arranged that the two sides of the disc are reflected in the mirrors; and thus the operator, when standing directly in front of the sighting box, can see both sides of the disc at once.

The two ends of the box facing respectively the candle and the gas burners are pierced with two holes, so that the rays from the two candles and the gas-light may fall on the centre of the disc.

Behind each of the lights, at a proper distance, so that their rays may not be reflected, is fixed a blackened screen, made of pine, painted with a mixture of vegetable black and turpentine, or light oil of petroleum, set with a little gold size.

In front of both candles and gas-light, astride the bar, are two other screens pierced in the centre, so that the rays of light from each end of the photometer may pass through to the sighting box.

It will be readily seen that this arrangement prevents the possibility of other light impinging on the disc than the direct rays from the lights to be compared, and thus a frequent source of error is eliminated from the experiment, as performed with other instruments.

The eyes of the operator are protected from the glare of the gas-light by a screen, not shown in the diagram, but which can readily be affixed to the two screens behind, and in front of the burner.

The rest of the apparatus consists of an experimental meter, fitted with a clock and an index, showing the hourly rate of consumption (as described in page 59), and a King's balance governor (as described in page 60). A pair of scales, capable of weighing to one-tenth of a grain, is fitted to receive the candle-holder, and weigh the candles whilst burning.

The Corporation photometer in Jewry Street is, in addition, fitted with two very accurately-constructed dry meters, and one wet meters capable of registering with the utmost precision the gas passed through them. By a simple arrangement of four fourway-cocks, any one of the two dry meters, or the water meter, may be instantly made to register the gas consumed by the burner at the end of the photometer, without in the least interfering with its regulation. The reason why there are three meters in this instrument is, because there are services laid in from three distinct companies who supply the City of London with gas; and to avoid any dispute as to the accuracy of any one of the meters used, another arrangement of fourway-cocks admits of the possibility of instantly changing them, so that the gas from any one of the three companies may be passed through any meters, according to choice.

The fourth way of both systems of cocks permits either different gases or meters to supply a jet or burner fixed in the place of the candles at the end of the photometer, whenever it is desired, for the purpose of testing, directly, one company's gas against another, or for other experiments.

Still further to ensure accuracy in his experiments, Dr. Letheby has provided himself with a spare dry meter, of similar construction with those before mentioned, which is at frequent intervals regularly connected in the place of one or other of them, when sent to be tested by the Official Meter Tester for the City of London.

FIXING THE PHOTOMETER.

The room selected for the photometer-room should be not less than 12 feet by 10 feet, dry and well ventilated, and warmed by a stove or hot-water pipes when necessary. The walls and ceiling should be blackened with a preparation of lamp-black and size.

The bench upon which the photometer and apparatus are to stand must be fixed upon brackets against the wall, or otherwise so solidly that the movement of persons walking about on the floor may not communicate any vibration to it.

The surface of the bench should be blackened with the same preparation as the screens are coated with, or covered with black cloth.

The apparatus may either be fixed in one continuous line, or, if desired, the meter and governor may be placed on a return bench.

If fixed in one line, the end carrying the measuring, regulating, and weighing apparatus may be lighted by means of a small burner covered by a copper reflector with a dark top, by means of which the light may be reflected on to this portion of the bench without interfering with experiments being carried on, or a cock placed on the front of the bench, ready to the hand of the operator, may be so arranged that by turning it off, the light may not be quite extinguished, but left burning low during the experiment.

The pressure of gas to the photometer must be regulated by a governor or gas-holder, to an uniform pressure of five-tenths.

DR. LETHEBY'S METHOD

OF PERFORMING AN EXPERIMENT FOR ASCERTAINING THE ILLUMINATING POWER OF GAS BY HIS PHOTOMETER AND APPARATUS.

Turn on the gas at the inlet of the meter, and fit on to the pillar at the gas end of the photometer any one of the 15-hole standard burners, described in pages 69, 70, and 71.

Light the burner, and, roughly adjusting it so that it does not smoke, allow it to burn until all the air has been got rid of from the apparatus and pipes, and the clear gas arrives at the burner.

Meanwhile, examine the water-line of meter, and see that the governor is properly in action and that the rest of the apparatus is in order.

Select a standard burner suitable for testing the gas, and fit it on in place of the one which has been burning, unless that is itself suitable.

The standard burners are arranged so that the supply of air to the interior and exterior of the column of flame shall be sufficient properly to consume the standard quantity of gas, of the illuminating power marked on them, without tailing over the top of the glass or over oxydizing the flame.

Should it be found that the first burner, tried as directed, does not consume the gas according to the above requirements, the next in order should be substituted for it till the proper one is found.

Under no circumstances should the gas be tested for illuminating power unless it is properly consumed.

Having selected the burner, provide it with a perfectly clear, thin glass chimney, 7 inches in height, and 1⅞ of an inch across the inside.

Select two sperm candles, hard and clean; fix them in the candle-holder, light, and hang them on the scales in the manner shown in the drawing of the photometer, so that they may get into burning order.

> The candles are in burning order when they present the appearance shown in Fig. 3, plate 11, with an even sharp-edged cup all round the wick, clean and comparatively dry.
>
> Candles burning with a round-edged cup, as shown in Fig. 4 of the same plate, contain paraffin, and therefore must not be used.

Adjust the rate per hour of the gas to the standard quantity, and stop the minute clock.

Draw up the weight of clock, and bring back the minute hand to zero.

Balance the *contra* side of scales, leaving the candles slightly the heavier.

Place one hand ready to start the clock, and at the moment the scales exactly balance, start it, and note the position of the hand which shows the hourly rate of consumption of the index; afterwards record the positions of the other time and gas hands.

Attach the candles to the photometer. If the candles do not appear likely to burn steadily—*i. e.*, show any tendency to gutter, smoke, or vary in their illuminating power—the disc must be adjusted every quarter of a minute, and the readings of the photometer scale recorded; if the contrary, observations need only be taken every half minute.

> The adjustment of the disc is made in the manner described in page 61, headed "Disc."

Having continued the experiment for ten minutes, blow out the candles as the bell is struck for the last minute, and note the position of the hourly rate of consumption hand, and afterwards the others, as at the commencement of the experiment.

Touch the wicks of the candles with a piece of sperm, to prevent them from smouldering off.

> This piece of sperm must be put into the candle pan before it is balanced; if the candles are allowed to smoulder, it causes trouble in getting them to burn properly for the next experiment.

Return the candles to the scale, and ascertain how many grains they have lost. If they have burned at the proper rate, 40 grains of material ought to have been consumed by the two candles.

Multiply the consumption, in grains, of the two candles by 6, and divide by 2; the quotient is the rate per hour at which the candles have been burning.

Examine the consumption of the gas. If the rate of 5 feet has been maintained, the hourly rate of consumption hand and the clock hand should remain together. If otherwise, divide the variation by 10, and add it to, or subtract it from, the standard rate, according as the clock hand is behind or before the gas hand, for in the first-mentioned instance the standard rate has been exceeded, and in the latter deficient.

Corrections for variations from the standard rate of consumption by either gas or candle are made by simple proportion; or if the rate of the gas has remained constant, that of the candle alone having varied, then in a shorter way, by the use of Dr. Letheby's table, which is on page 91, by his kind permission, inserted. Should, however, variations have occurred in both, then Sugg's table, page 83, or those calculated from it, may be used.*

See Form of Experiment as exhibited on page 90.

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* *Photometrical Tables for correcting Experiments to the Parliamentary Standards by inspection;* by William T. Sugg, A.I.C.E.

FORM OF EXPERIMENT.

DATE—*Jan. 24th, 1867.*

DESCRIPTION OF TESTING BURNER.

Letheby Argand, 15-h. 7-in. Chimney.

PRESSURE AT POINT OF IGNITION.

0·45 of an Inch of Water.

	Cub. Ft.
Index of Meter at COMMENCEMENT of Experiment:—	
Hourly rate of Consumption Hand .	. *4·1* .
Actual ,, ,, .	. *3·0* .
Ten-minute Hand of Clock	*Zero.*
Index of Meter at END of Experiment:—	
Hourly Rate of Consumption Hand .	. *2·4* .
Actual ,, ,, .	. *2·25* .
Ten-minute Hand of Clock	*Zero.*
RATE of Consumpt: per hour of BURNER. .	. *5·17* .

Readings of Photometer.		
1st Minute .	*7*	*0*
Half .		
2nd Minute .	*7*	*0*
Half .		
3rd Minute .	*7*	*1*
Half .		
4th Minute .	*7*	*0*
Half .		
5th Minute .	*6*	*9*
Half .		
6th Minute .	*6*	*9*
Half .		
7th Minute .	*6*	*9*
Half .		
8th Minute .	*7*	*0*
Half .		
9th Minute .	*7*	*0*
Half .		
10th Minute .	*7*	*0*
	69	*8* *2*
Average reading of Phot.	*13·9*	*6*

Rate of Consumpt: of 2 Candles.

2)42 grs.

—

21 × 6 = *126* **grs. per hour,**

Or by reference to the Table.

Result—*5·17* cub. ft. of Gas = *13·96* candles, at *126* grains per hour.

Corrected to standard rates. (*See* Tables.)

14·13 Candles.

Signed,

NOTE.—The Figures in Italics are intended to be filled up by the Experimenter.

Table for ascertaining the Standard Value of the Illuminating Power of Gas when burnt at the rate of 5 cubic feet per hour from any experimental observation (Dr. Letheby).

Weight of Candles consumed per Hour.	Value of Illuminating Power of the Gas in Standard Quantity (120).								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Grains.									
110	0·917	1·833	2·750	3·667	4·583	5·500	6·416	7·333	8·250
111	0·925	1·850	2·775	3·700	4·625	5·550	6·475	7·400	8·325
112	0·933	1·867	2·800	3·733	4·666	5·600	6·533	7·466	8·400
113	0·942	1·883	2·825	3·767	4·708	5·650	6·592	7·534	8·475
114	0·950	1·900	2·850	3·800	4·750	5·700	6·650	7·600	8·550
115	0·958	1·917	2·875	3·833	4·791	5·750	6·707	7·666	8·625
116	0·967	1·933	2·900	3·867	4·833	5·800	6·767	7·734	8·700
117	0·975	1·950	2·925	3·900	4·875	5·850	6·825	7·800	8·775
118	0 983	1·967	2·950	3·933	4·916	5·900	6·883	7·866	8·850
119	0·992	1·983	2·975	3·967	4·958	5·950	6·942	7·934	8·925
120	1·000	2·000	3·000	4·000	5·000	6·000	7·000	8·000	9·000
121	1·008	2·017	3·025	4·033	5·042	6·050	7·057	8·066	9·075
122	1·017	2·033	3·050	4·067	5·083	6·100	7·117	8·134	9·150
123	1·025	2·050	3·075	4·100	5·125	6·150	7·175	8·200	9·225
124	1·033	2·067	3·100	4·133	5·167	6·200	7·233	8·267	9·300
125	1·042	2·083	3·125	4·167	5·208	6·250	7·292	8·333	9·375
126	1·050	2·100	3·150	4·200	5·250	6·300	7·350	8·400	9·450
127	1·058	2·117	3·175	4·233	5·292	6·350	7·408	8·467	9·525
128	1·067	2·133	3·200	4·267	5·333	6·400	7·467	8·534	9·600
129	1·075	2·150	3·225	4·300	5·375	6·450	7·525	8·600	9·675
130	1·083	2·167	3·250	4·333	5·417	6·500	7·583	8·667	9·750
131	1·092	2·183	3·275	4·367	5·458	6·550	7·642	8·733	9·825
132	1·100	2·200	3·300	4·400	5·500	6·600	7·700	8·800	9·900
133	1·108	2·217	3·325	4·433	5·542	6·650	7·758	8·866	9·975
134	1·117	2·233	3·350	4·466	5·583	6·700	7·817	8·933	10·050
135	1·125	2·250	3·375	4·500	5·625	6·750	7·875	9·000	10·125
136	1·133	2·267	3·400	4·533	5·667	6·800	7·933	9·067	10·200
137	1·142	2·283	3·425	4·567	5·708	6·850	7·992	9·133	10·275
138	1·150	2·300	3·450	4·600	5·750	6·900	8·050	9·200	10·350
139	1·158	2·317	3·475	4·633	5·792	6·950	8·108	9·267	10·425

This table is constructed so that, when the gas is burning at the rate of five cubic feet per hour, the observations of the hourly rate of burning of the candle and the illuminating power of the gas may be calculated into the standard value of 120 grains consumption of candle per hour. This is done, either by multiplying the first number (column 1), after the observed weight of the hourly consumption of the candle, by the observed value of the gas, and the product is the value of the gas in standard candles;

or, by adding up the several numbers which correspond in the columns headed by the successive figures of the illuminating power of the gas: for example, suppose the candle burnt at the rate of 126 grains per hour, and the illuminating power of the gas, as the mean of ten observations, was 12·14. According to the first mode of calculation, the number in column 1, which is opposite 126, is 1·050; this, multiplied by 12·14 (the observed power of the gas), gives 12·747 as the illuminating power of the gas in standard candles. According to the second mode of calculating the power, the several numbers of the columns opposite 126, which correspond to the figures of the illuminating power of the gas (12·14), are as follows:—

1 . . 10·50
2 . . 2·10
1 . . 0·105
4 . . 0·042

12·747=illuminating power in standard candles.

THE JET PHOTOMETER.

Some years ago it came under the observation of Mr. George Lowe, then Engineer-in-Chief of The Gas Light and Coke Company, that the height of a flame of gas burning under a well-regulated and constant pressure from an aperture of unalterable dimensions depended, in a remarkable manner, upon the illuminating power of that gas; and by a series of experiments, extending over several years, he was fully confirmed in his belief.

It is but just to say, however, that it is very possible that this fact may have been noticed by others, who, however, were far from considering it as a reliable indication, because their experiments with it were of too crude a nature to enable them to form a just appreciation of its value; and who, therefore, abandoned it.

But the experience of Mr. George Lowe soon enabled him to arrive at conclusions respecting the proper method of fairly testing the correctness of his idea; and, unmoved by apparent inaccuracies, he carefully traced out the errors from which they arose, and succeeded in establishing the following data as a basis upon which to construct Photometers upon this principle.

That it is necessary that the means for indicating the pressure at the point of ignition of the flame should be excessively delicate. That the jet should be formed of a material unalterable by the action of heat, damp, or wear, and which should be as much as possible a non-conductor of heat.

To meet the first of these requirements, he made use of a King's pressure gauge, the dial of which was divided into tenths of an inch of water, each tenth being magnified to about three times its natural size; and to meet the second, he chose a jet made of porcelain.

The regulation of the delivery of the gas was effected by means of a small cock with a long lever, and uniformity of pressure was maintained by the aid of a very nicely constructed gas-holder.

Added to this, the apparatus was set up close to a carefully arranged Photometer, so that the value of any given height of flame could be ascertained with tolerable accuracy in terms of the wax or sperm candle.

With this apparatus he made a large number of experiments, extending over two or three years, and it was to the experience thus gained and imparted by him to the present editor, that Lowe's Jet Photometer owes its existence. The improvements upon the original apparatus made by the last-named were, the construction of a more delicate King's pressure gauge; the substitution of a smooth steatite jet for the porcelain one used by Mr. Lowe; the enclosure of the whole in a case with a glass front, so that it might in no wise be affected by the draught caused by the approach or breathing of the experimenter; and the system of gauging the height of the flame by means of two scales, the one engraved on the glass front, and the other on a piece of enamelled white glass at the back of the box behind the jet.

Subsequently to these improvements the original apparatus for maintaining a constant pressure has been superseded by the introduction of a small double dry Governor, which effects its object with great precision.

A great number of these instruments are now in use in different parts of the world, and the most eminent authorities have given their adhesion to the principles propounded by the talented engineer, whose name is so imperishably connected with the rise and progress of the science of gas manufacture and distribution.

Valuable testimony is thus abundantly given, that properly constructed the Jet Photometer is really accurate, and that the failures of those who have abandoned it have been due probably to the use of metal jets, inefficient pressure guages, or to other causes, which Mr. Lowe early discovered and remedied. Opposite this page (Plate 14) is a drawing of the instrument (represented as at work with Cannel gas of 22 candles illuminating power) as it is now manufactured, which will, doubtless, with some further explanation, be sufficient to make it thoroughly understood.

The instrument consists of a very delicate King's pressure gauge, similar to that described on page 51, but with a scale so large that the one-hundredth of an inch can be easily read off, one-tenth of an inch variation in the level of water being equivalent to one inch on the scale; the needle is suspended on finely-polished cone pivots, so that the least increase or decrease in the pressure on the surface of the water is immediately communicated to the pointer, and the alteration in the level shown on the index ten times its real magnitude.

The gasways are some thousand times larger in sectional area that the jet itself, which is fixed on the top of the arch of the pressure gauge, in order to ensure the greatest possible accuracy in the performance of the instrument.

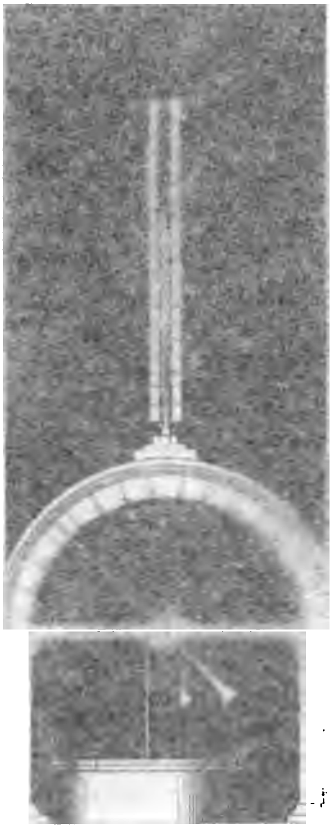
A cock is fixed at the base of one of the columns supporting the scale, in order to facilitate the escape of gas from the instrument when it is desired to make an examination of the water-line.

Directions for Fixing the Jet Photometer, and putting it in Working Order.

In fixing the instrument care must be taken to have it placed perfectly level upon a firm base, so as not to be affected by vibration, or other disturbing causes.

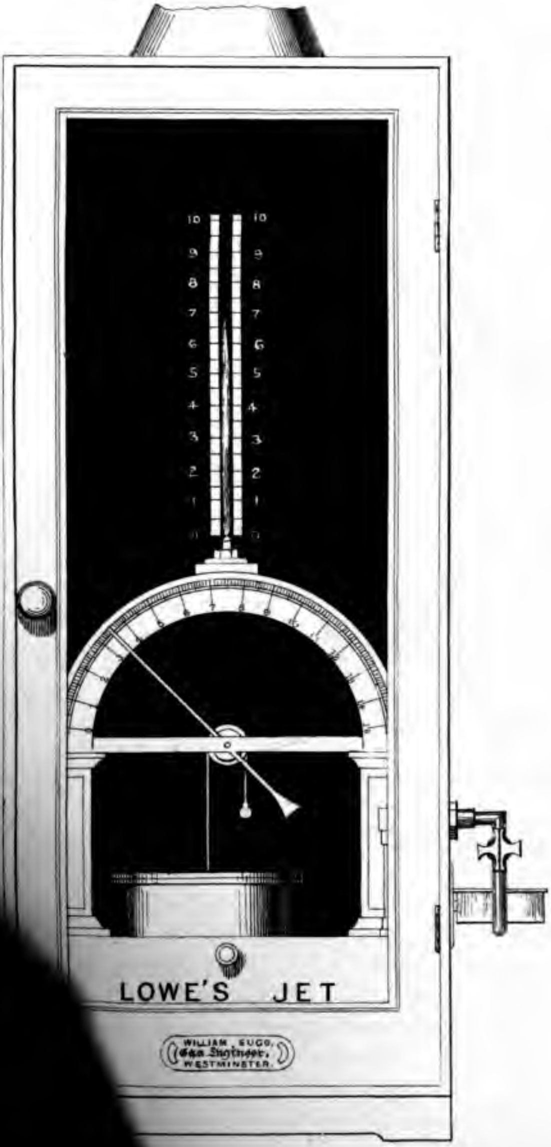
> Let it be borne in mind that, should it be thought desirable to convey the products of combustion from the room in which the instrument is fixed by means of a tube, it is indispensable that an interval of at least six inches should intervene between it and the top of the funnel, otherwise the current of air, whether upward or downward, will materially affect the height of the flame, and consequently prejudice the success of the experiment; and in no case should the cap of the funnel be removed.

Now proceed to fill the tank with water up to the overflow line.



Pl 14

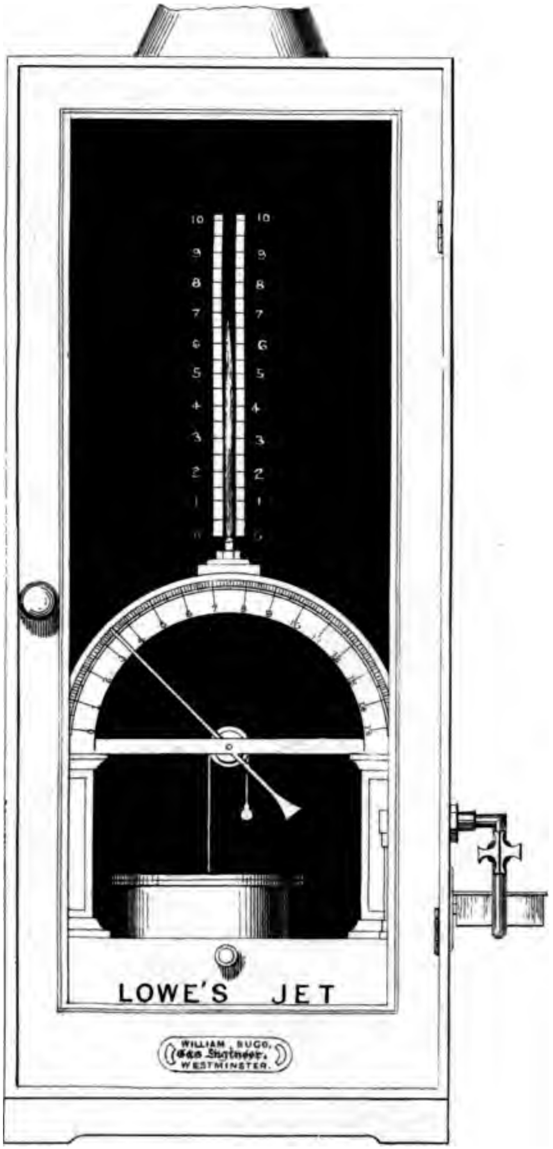
LOWE'S JET PHOTOMETER



lbank St Westminster

Pl. 14

LOWE'S JET PHOTOMETER



Entd. at Stationers Hall.   W Blanchard & Sons 62 Millbank St. Westminster

Hang on the float so that it falls from the left side of the wheel.

Let the balance weight cord have one turn round the wheel, and it will then hang close up to the wheel on the right side.

Hold the wheel with the thumb and finger of one hand, and shift the pointer (which is loose on the shaft) with the other, till it stands at zero, taking care that it works freely.

The steel centres, upon which the wheel works, must be kept so that the shaft will work loosely between them.

> It is necessary once a day to turn off the inlet and open the vent cock, in order to test whether the instrument will start from zero; and it should always be put to zero if found under or over.
>
> The alteration, if any, is caused either by the evaporation of the water, or by the effect of the atmosphere upon the float line.

Connect the apparatus with the gas, and adjust the double Governor in the following manner:—Turn on the regulating cock, and after weighing down the gas-holder nearest it, adjust the weight of the other one so that it gives a pressure of about 4 or 5-tenths greater than will be required at the point of ignition of the jet—say one inch. This being done, release the first-mentioned gas-holder, and the instrument is then ready for use.

> If the instrument is connected with a main liable to great variations of pressure—say from 4 to 8 or from 8 to 12 inches—an additional governor must be fixed on its inlet.

Method of ascertaining the Value of the Jet in terms of the Standard Sperm Candle.

Connect the instrument to the inlet of the meter belonging to a Parliamentary Photometer, *i. e.*, one constructed on the Evans or Letheby principle, so that they both may be supplied with gas from the same source.

Ascertain the illuminating power of the gas by comparison with the standard candle in the manner previously pointed out; then regulate the pressure at the point of ignition of the Jet Photometer by means of shot or small weights placed in the pan of the gas-holder nearest the regulating cock, until the flame attains to half the height in inches of the corrected value of the gas in candles.

> Thus, for example, suppose the illuminating power of the gas is proved to be 13 candles—then adopting the formula just mentioned, the flame should stand at 6½ inches.

Mark the pressure at the point of ignition as shown by the index, this being the initial or standard pressure; and as long as the same jet is used the index must be brought to it before taking an observation. If the Jet Photometer is allowed to remain for some time thus connected, and observations be made of the height of the jet every time the illuminating power of the gas is tested with the Parliamentary instrument, the value of the principal divisions of the scale, *i.e.*, those nearest the standard, will, after a series of experiments, be accurately determined. The scale once adjusted the instrument may be removed to any other part of the works.

> The series of experiments for this purpose must be made in strict conformity with the directions given at pages 79 and 87, care being taken to eliminate the results of those in which the consumption of the candles has exceeded or fallen short of the standard rate by more than 3 grains.

It is not intended by the formula given to lay down an arbitrary standard for the working of these instruments, because the standard pressure and height of the jet may be fixed at any point according to circumstances, and so long as the value of each division in candles has been worked out in the manner described the indications of the jet may always be relied upon.

To keep it always in order it is only necessary to attend to the few points mentioned in the directions for working, and above all things to take care that the jet is not tampered with. It will not require cleaning very often, and when it does it should be dusted with a brush, or the orifice cleaned out with a bristle; nothing hard should be used for that purpose.

When the Jet Photometer is employed for indicating the illuminating power of Cannel gas, the system of adjustment of the standard pressure and of the height of flame is slightly varied, for if the gas is of the illuminating power of 20 or 25 sperm candles, the pressure suitable for 13 or 14 candle gas would be too much, and give a flame too unsteady to be readily gauged; so in order to obviate this objection, it is usual to reduce the pressure at the point of ignition to such a degree that the flame from the gas may rise to the height of 7 inches for 20 candle gas. In all other respects they are treated in a similar manner. The uses to which these instruments are usually put on a gas-works are:—To give immediate indication to the attendant on the exhauster when he is working too fast, instead of employing the ordinary fish-tail or batwing burner usually fixed in the engine-room, and which is a very inefficient means for the end in view: To enable the night and day foremen by an instant inspection to ascertain if the make of gas is of the standard quality, and to afford the engineer a ready means of knowing the value of the gas he is sending out of his works to the public.

To these uses Mr. F. J. Evans has lately added another, which is not the least important of the whole, and which is to give, when connected with the experimental apparatus, the approximate value of every portion of a charge of coal under the process of carbonization, thereby enabling the experimenter testing samples of coal for gas-making purposes to estimate with tolerable precision the amount of really good gas to be obtained from each.*

It may be interesting to many readers of this work to know that Mr. Claudio Gil, Engineer of the Barcelona Gas Works, Spain, who will be favourably remembered as a visitor to some of the largest gas producing establishments in England, has made known to the editor a method of ascertaining the specific gravity of coal and other gases as compared with air by means of the Lowe's Jet Photometer.

This method is as follows:—

He fills a 5-ft. gasholder with gas, and after allowing it to stand for a short time so that it may acquire the temperature of the room in which it is placed, he allows its contents to flow away through the unlighted jet of the Photometer at a constant pressure, until the gasholder is empty, carefully noting the time required to perform this operation. Then immediately introducing sufficient air, he lets it blow away to clear the fittings of gas, after which he fills up the holder with air, and allows it to flow away in the same manner as the gas, also noting the time required for its escape.

From these data he determines the specific gravity of the gas he makes, without having occasion to correct for temperature or pressure of the atmosphere.

He also states, as the result of his experience extending over

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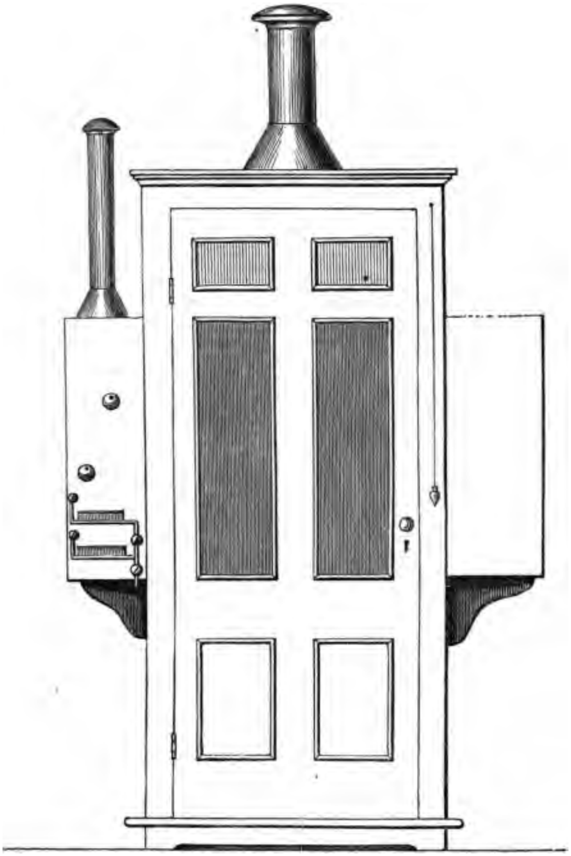
* When the Jet Photometer is employed in this manner, it is necessary to alter the arrangement for the supply of gas, by taking it direct to the square base upon which the jet rests, and so closing the orifice which conveys the gas from the body of the pressure guage to it, that the pressure may be communicated to the surface of the water without allowing the mixed gas contained in the lower chamber to affect that which passes out at the jet.

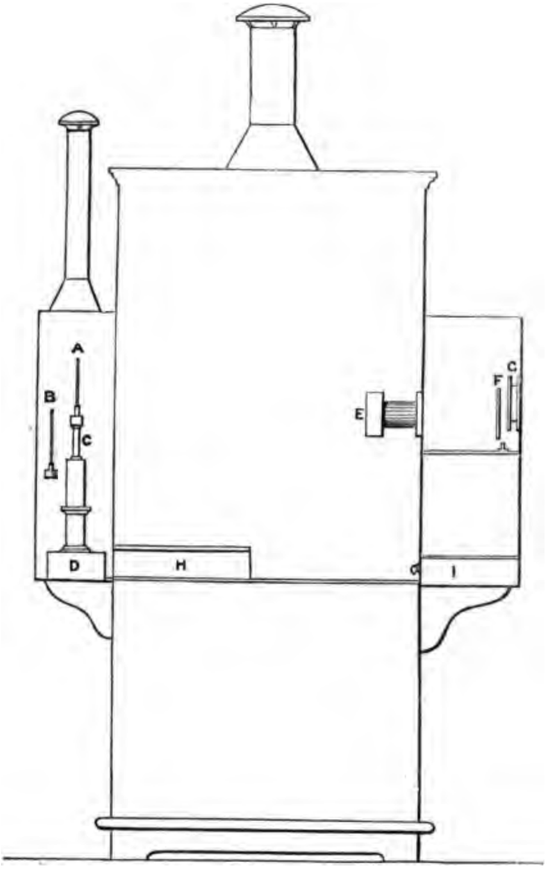
KIRKHAM & SUGG'S
REGISTERING JET PHOTOMETER.



ELEVATION OF FRONT.

Pl. 16.

KIRKHAM & SUGG'S
REGISTERING JET PHOTOMETER.



VERTICAL SECTION.

The paper, which is by permission printed *in extenso*, is as follows:—

DESCRIPTION OF A SELF-REGISTERING PHOTOMETER.

" The subject on which I propose to offer a few observations is the application of one of the most brilliant discoveries of the age, photography, to photometry in such a manner, as to produce a permanent and accurate record of the illuminating power of the gas, either as it is delivered into the gas-holder or as it issues from the gas-works. We are indebted for the instrument by which these results are obtained, to the combined labours of Mr. Kirkham, of the Imperial Gas Works at Fulham, and Mr. Sugg, of Westminster, who, aided by Mr. Glaisher, of the Royal Observatory, at Greenwich, have for some time been engaged in perfecting in its details the instrument I am now about to describe.

The " durability test," as it is usually called, has long been a favourite mode amongst Scotch gas engineers of determining the comparative value of coal gas, as it is well known that the length of the flame issuing from a jet of given aperture will vary according to the quality of the gas, the richer gas giving the longer flame, and the poorer gas the reverse. Dr. Fyfe, of Aberdeen, availed himself of this effect many years ago, to make the earliest recorded observations on the comparative values of different gases, by determining the time during which one cubic foot of gas would supply a jet flame of a certain uniform height; and, till the Bunsen photometer was perfected by Mr. Alfred King, the durability test was the one most relied upon by gas engineers in making such comparisons.

" Some years ago, Mr. George Lowe suggested a method of testing the illuminating power of gas, by means of a jet burning from an aperture of known size, and issuing under a known pressure, and he always found, by the results of a vast number of experiments extending over several years, that the jet he had employed gave the same height of flame for the same quality of gas, the pressure at the point of ignition always remaining constant at six-tenths of an inch.

" The system he pursued in conducting these experiments, was this:—

" 1. The aperture of the jet was gauged, by means of a wire exactly fitting into it.

" 2. The pressure at the point of ignition was regulated to six-tenths of an inch, the pressure being shown on a King's pressure-gauge delicately balanced, each tenth being magnified to about four times its natural size.

" 3. The height of the flame was measured by means of a wire fixed at the back of the flame and bent over at the top, so that when the flame reached the height of 6 inches, it just touched the wire.

" By nearly simultaneous observations taken by the bar photometer upon the same gas, he established the value of a 6-inch flame from the jet to represent 12 candles when the gas was consumed in an Argand burner at the rate of 5 feet per hour, and he found that when the gas rose in illuminating power to 13 candles his jet was just half an inch longer than the wire standard; and, on the other hand, if it fell to 11 candles, it was as nearly as possible half an inch shorter.

" Lowe's jet photometer was subsequently modified by enclosure of the jet in a box, the substitution of a more delicate pressure-gauge, capable of showing the 100th of an inch of water, for the one he employed, and, instead of the wire, a scale at back of jet corresponding to another scale scratched on the glass serving as door fixed in front of the jet. These photometers have now become very generally known, and the theory asserted by Mr. Lowe has been found to be as nearly as possible correct in practice.

" Twelve months ago the idea struck Mr. Kirkham that the indications of the photometer might be recorded throughout the hours of the day and night by means of photography, and thus be made to give as it were a chart of the illuminating value of the gas supplied to the public or made during each hour's working. Mr. Sugg associated himself with him, and the result of their united labours is the registering jet photometer now before you.

" A close box, rectangular on plan, to which no light can enter when the door is closed, except through the windows, filled in with red-coloured glass, is fitted on one of its sides with a jet photometer, and on the opposite side with a photographic camera. The back of the photometer is fitted with a piece of brass, having a slit in it about an eighth of an inch wide. Crossing this slit externally, at certain intervals from bottom to top, are pieces of wire, intended to produce the lateral marks upon the registering plate where affected by the light of the illuminating power jet. A short distance below the lowest of the wires a prism is fixed in a vertical position, in the same line with the jet. This prism is also provided with wires placed laterally across it, and their use is to produce the lateral lines upon the registering-plate on that part where the pressure at the point of ignition of the jet is recorded.

" These wires are fixed at regular intervals, and the distance between each corresponds to one-tenth of an inch of pressure. The base line is at the top, in order that the distance between the jet registrations and the pressure registrations should be constant, and for convenience.

" The pressure on the illuminating power jet is maintained by means of a double governor, and a very delicately-balanced King's pressure-gauge is provided, through which the gas flows to the jet, so that the least variation of pressure, even to less than the 100th of an inch, is plainly perceptible. The importance of these arrangements will be immediately perceived when it is considered that the entire success of the experiment depends upon the gas being made to issue at a uniform pressure. The pressure-gauge is also provided with an apparatus for altering its water level without opening the door of the photometer. This is simply a solid plunger closely fitting to the inside of a cylinder, the middle of which is level at the true water line of the pressure-gauge. Above the plunger is fixed a screw, which either raises or depresses the plunger, and produces a contrary action on the water line of the pressure-gauge, so that the pointer can be brought to the zero point with speed and accuracy. If it were necessary always to open the door to do this, the sensitive plate might be spoiled by the action of daylight or strong gaslight.

" The jet having been turned on, lighted, and adjusted to its proper pressure, shines through the aperture at its back, so that its image is clearly reflected through the lens on the registering-plate, the lateral wires showing its height.

" These indications would, however, be quite useless unless it was certain that the pressure had been maintained at its proper standard, and to give this information the prism before spoken of is employed.

" A light adjusted by means of a double governor, similar to the one employed for regulating the pressure on the jet, is made to burn in such a position that its rays may fall upon the side of the prism, and, by refraction, pass through it, throwing its rays on to the lens of the camera, by which it is in turn transmitted to the sensitive plate.

"In order to show what pressure is indicated by the pointer on the dial of the pressure-gauge, the following means are made use of:—

"On to the shaft which carries the pointer is fixed a small grooved wheel, exactly corresponding in diameter to another and a similarly grooved wheel, fixed about 4 inches above and perpendicular to it, so that a light silk line may run over them both. This line, being attached to one part of the periphery of the lower wheel, is made to pass over the upper one, and its remaining end is tied on to a small weight; thus the motion of the lower wheel is exactly imitated by the upper one, and this upper one being provided with a cycloid fixed to its shaft, it follows that any portion of a revolution of the main shaft of the pressure-gauge may be made to cut off the li ht shining through the prism to any degree, according to the rising or falling of water in the pressure-gauge cistern.

"When the gas is shut off from the pressure-gauge, and the pointer falls to zero, the cycloid cuts off all the rays passing through the prism, except a thin line, which is the base line shown on the plate. Any alteration in the thickness of this line, will show whether the pointer was above or below zero, and exactly how much to the 100th of an inch; and when the jet is lighted, how much pressure is on it, for there will be as many spaces as there are 10ths of pressure shown on the gauge. In order, then, to get a satisfactory plate, the photometer-jet should not be lighted for one hour at starting, so as to give the pressure-jet an opportunity of recording its base line; and the photometer-jet should be turned out on the 23rd hour—*i.e.*, eleven o'clock—to show that the water line of the pressure-gauge has not been interfered with, or if from any cause whatever it has varied, then to what extent. The adjustment of the cycloid can easily be made when the photometer-jet is turned off, by means of the small mirror fixed in front of the pressure-gauge opposite the zero line.

"At such a distance from the back of the jet photometer as will be sufficient to produce the image of the jet and pressure-gauge quarter full size upon the sensitive plate is fixed a No. 3 Ross's lens, with arrangements to enable it to work with a small actinic power, because although the image it has to reproduce is shining directly on to the lens, yet the actinic power in the gas flame is so small, that without such a lens the rays would not have time to affect the silver on the plate sufficiently to make a good negative during the time occupied by the plate in traversing the point where the image falls.

"Within the focus of this lens is laid down a brass rail, and upon that the slide containing the sensitive plate is made to roll by means of a small lever clock fixed immediately above the slide, and gearing with it by means of a rack on the slide and a toothed wheel on the clock. A simple arrangement of a lever with a roller on it working into a groove cut in the top of the slide serves to connect it with the clock and keep it in its place. From the top to bottom of this slide are stretched wires which divide the plate into 24 hours, and as each of these pass across the point where the images of the jet and pressure-gauge fall on the plate, it leaves its shadow-mark on the plate, producing the vertical lines, which are hours.

"Between the jet and the pressure-gauge on the photometer side will be seen a small prism illuminated by the rays of the pressure-jet, and the image of this prism falls on the sensitive plate between the base line of the photometer-jet and the base line of the pressure-gauge. The office of this prism is to illuminate the stencilling-plate carrying the numbers of the hours and the date of the month and year during which the record is made.

"The plates made use of for obtaining the information required are those known as Dr. Hill Norris's dry stereoscopic plates, and they are prepared in the following manner:—A clean glass plate is coated with ordinary iodized collodion, and immersed in a bath of nitrate of silver. After remaining some minutes in the bath, in order to allow the silver in the bath to form the iodide of silver upon the glass plate, by combining chemically with the iodine contained in the collodion, it is withdrawn, and washed upon its surface with a small quantity of distilled water, in order to remove any free nitrate of silver which may be floating about on it. After standing for a short time to drain, it is coated with gelatine, so as to secure the iodide of silver, and prevent dust getting to the collodion film.

"These plates, when dry, are sensitive to the action of light, and must be packed away in a dark place, or in a place where no light can fall upon them except through the medium of a red glass, through which the actinic power of light will not pass at all.

"Now, although the collodion film while wet would be readily affected by the rays of a candle even, yet when prepared for dry plates it is not possible to make them retain their sensitiveness to such an extent, and therefore it is that a lens is required whose chemical power shall be as great as possible, so as to act upon the plate in the shortest possible time.

"The process of developing the plates after their exposure is as follows:—When taken from the slide no mark is perceptible upon the plate, because although the silver contained in the film is changed in its nature by the action of the light, yet the effect of this change will only be apparent when it is brought into connexion with some organic substance which shall in combining with it change its colour, at the same time leaving without change that portion of silver not touched by light.

"The substance most easily and inexpensively employed for this purpose is gallic acid, of which a solution is made by simply filling a bottle with distilled water and throwing into it some gallic acid till the water is saturated, ensuring always that it is so by taking care that some grains remain at the bottom of the bottle.

"To make this solution with cold distilled water it is requisite that the water should remain in contact with the acid at least 24 hours. Two ounces fluid of this solution is poured into a glass dish, and to it is added 15 drops of a solution of nitrate of silver—20 grains of silver to one ounce of water. Into this the plate, after being taken from the slide, is immersed, care being taken that the immersion be done so that the solution contained in the dish flows over the plate immediately, without leaving any dry places.

"After about a quarter of an hour the image will be seen upon the plate, or, in photographic language, 'the image will develop itself in all its details under the influence of the developer.' It will only then be necessary to increase the intensity, or, in ordinary words, to make the image blacker, by adding about 15 to 20 drops of the same solution of silver to the developing solution in the tray; about a quarter of an hour or 20 minutes will be quite sufficient, and if it is not required to print from, the plate may be washed with a little water and allowed to dry.

"To use the plate for copying, it is first necessary to remove the iodide of silver which has been unaffected, and this is done by immersing the plate in a bath of hyposulphite of soda or cyanide of potassium, both of which will remove the iodide not touched by the light, without in the least injuring the picture. The plate should then be varnished to protect it from injury, and this is done simply by pouring a little prepared varnish on to the glass so as to cover it, and letting it run off into the bottle again.

"The paper for printing upon is that known as 'papier Saxe,' and is prepared somewhat in the following manner:—A piece of paper is floated on a solution of chloride of barium, and afterwards upon a solution composed of distilled water and white of egg, which gives it a glazed appearance.

"Prepared in this way, it is to be obtained of any photographic chemist; and in this form it is quite insensitive to the action of light, and to prepare it for printing it is only necessary to float it on a bath of nitrate of silver solution, containing about 60 or 80 grains of nitrate of silver to one ounce of distilled water, and hang it up by one corner in a dark room or box till it is dry. When dry it is laid on the negative with the prepared side of the paper facing and touching the face of the negative. Both are then put in a printing-frame, and exposed to the action of daylight or sunlight till the edges of the paper become quite bronzed. Then the paper is removed, and after being well washed with common water to remove any untouched silver which is soluble, leaving behind on the paper that portion of silver upon which the light has shone, which has become insoluble, it is immersed in a bath of distilled water containing a small portion of chloride of gold, which has the property of giving a tone of either deep chocolate brown or black, according to the quantity of the gold employed and the time during which it has been allowed to remain in the bath. It is then taken from this bath and immersed in a bath of hyposulphite of soda till the paper appears clear upon holding up to the light, after which it is thrown into hot water and allowed to remain till all the hyposulphite has been dissolved out of it and thoroughly removed. Should any remain it will crystallize upon the paper and finally destroy the picture.

"This process, although when described at length appearing complicated, is in reality extremely simple, and such as may be performed by any ordinary person perfectly with a few hours' practice.

"In the development of the plate it will in practice, however, only be necessary to immerse the plate in the developing bath and allow it to remain shut up in the box till it is done; no harm would result if it were left all day in this bath.

"It is, of course, large establishments only that can avail themselves of such instruments, the chief practical value of which is to disprove by unquestionable evidence the statements of trading agitators who habitually misrepresent, or unskilfully conduct experiments on the illuminating power of gas, and who obtain some credit because the details of no concurrent counter-experiments can be produced to contradict theirs. In such establishments photographic photometers must henceforward be as necessary as pressure registers."

The instrument from which the drawings are made is fixed at the Fulham station of the Imperial Gas Light Company; and the lithograph Plate 17 is a copy of the photographic register of the illuminating power of the gas supplied to the public from that station during the hours of the day and night, 10th and 11th of May, 1866.

It is fair to state that the quality of the gas was made to vary more than it otherwise would have done, for the purpose of showing the delicate action of the instrument.

The explanation of the diagram is as follows:—The lines at the bottom show the pressure under which the jet was burning, and each line represents one-tenth of an inch of water. The thick white line at the top is the base line, and the mark under 12 on the left hand, and that under 11 and 12 on the right hand, show that the pointer of the pressure gauge was at zero when the experiment was commenced and stopped. The whole of the pressure register shows that the jet was burning during the whole of the experiment under a pressure of six-tenths, without variations greater than the 100th of an inch. The upper part is the photograph of the flame of the jet, one quarter full size; and in this particular instance the flame reached the height of 7 inches when it was equal to 14 candles, 6 inches when it was equal to rather more than 12 candles, and a little over 6½ inches when it was equal to 13 candles.

The vertical lines are the hours.

TAR AND AMMONIACAL LIQUOR.

The quantity of tar and ammoniacal liquor in the coal will be ascertained by running off those compounds from the ⅝ brass cocks in the condenser. Both vary much in their character, according to the quality of the coal and the temperature at which it has been distilled. If the retort is worked at a high heat, the tar is neither so large in quantity nor so good in quality as when a low heat is employed. The liquor from bituminous coals contains generally a great deal more ammonia than that from the Cannel or Boghead seams, but the tar is not nearly so rich in hydro-carbon compounds, and is specifically heavier than that obtained from those sources.

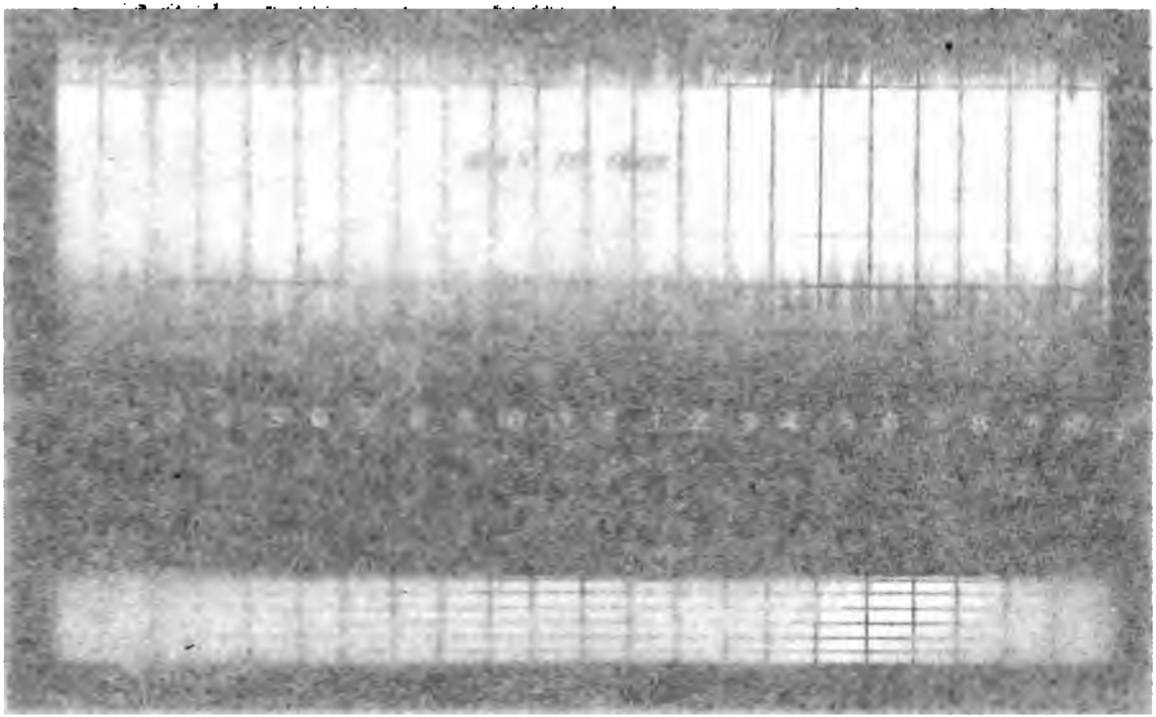
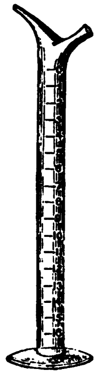


DIAGRAM OF PLATE

The strength of the ammoniacal liquor is generally determined in the following manner:—the value of the liquor depends upon the quantity of commercial salt it is capable of producing, and in order to ascertain this, sulphuric acid is mixed with a given quantity of liquor till the solution is neutral, which is known by its not reddening blue litmus paper. The test acid employed is called " ten per cent. acid," and is prepared in the following manner:—one pound of strong sulphuric acid (specific gravity, 1845) is mixed with water till the solution measures exactly one gallon, the specific gravity of which will be found to be 1068·2. If, now, a glass vessel, divided into sixteen exactly equal parts and graduated accordingly, be filled with this test solution, each division will represent one-sixteenth of a pound, or one ounce of sulphuric acid. Such an instrument as this is called an alkalimeter, and is represented in the adjoining figure. Fill the alkalimeter to the line marked zero with ammoniacal liquor, and pour it into a dish; wash out with clean water, and pour the washings into the dish also. Now fill with the test acid to zero, and pour into the dish, carefully stirring up the mixture at the same time with a glass rod. Note the point of saturation, which will be ascertained by the mixture slightly reddening litmus paper. Read off the number of ounces of test acid poured off from the alkalimeter—say six ounces, or six divisions rather—and this will represent the strength of the liquor, which will be called "six-ounce liquor" accordingly.



It is necessary to test this acid solution occasionally, not only by its specific gravity—which ought to be 1068·2—but also by saturation with carbonate of soda. The carbonate of soda of commerce is taken and thoroughly dried at a red heat so as to drive off all the water of crystallization; if the test acid is of the proper strength, 1,000 grains of it ought to saturate 110 grains of this dry salt.

Litmus paper is used to ascertain when the solution is rendered neutral: if acid, the blue colour of the litmus will be changed to red; if alkaline, the litmus will retain its colour; if neutral, the litmus will be changed to a purple colour.

QUALITY OF COKE.

The quantity of ash in the coke is ascertained in the following manner:—the coke to be examined is first carefully weighed, and then transferred to the furnace, shown in the adjoining figure. This is a small fire-clay furnace, provided with various stoppers and sight holes, and is used principally for the assaying of metals. A strong gas jet, passing through the grating in the bottom is made to come in contact with the coke, which, being thus easily kindled, and a good draught maintained through the chimney, is left to burn itself out. The ash is then carefully collected and weighed, and being compared with the quantity of coke originally put into the furnace, the percentage of ash is determined.* If it is desired to determine the nature of this ash, it can be easily done by treating it at the blow-pipe with a weak solution of nitrate of cobalt. If magnesia is present, it will render the flame a pale flesh colour; if alumina, it will be blue; if alumina and oxide of iron, a dirty green; and if lime, a greyish black.

The next process is to determine the quantity of sulphur existing in the coal or coke. The following method was first suggested, I believe, by Mr. Lewis Thompson, a gentleman to whom the chemistry of gas lighting is more indebted than to any other. A mixture is first prepared consisting of 100 grains of finely pounded coke or coal, and about 30 grains of pure carbonate of soda, also reduced to a fine powder. This is put into a small iron ladle and exposed to the heat of a brisk fire. The carbonaceous particles of the coal or coke are soon burnt off, and the sulphur combines with the metallic portion of the soda, forming sulphuret of sodium. This is now to be sprinkled with powdered nitrate of potash as long as deflagration continues, and then allowed to remain at a bright red heat for some minutes; by this means the sulphuret of sodium is rapidly converted into the sulphate of soda. The ladle is now allowed to cool, when the salt is to be dissolved by means of boiling water. This solution must now be filtered in the usual way, and then saturated with nitric acid. A strong solution of nitrate of baryta is next to be added, when a precipitate of sulphate of baryta is thrown down. This must be collected on a filter paper, previously weighed, well washed with boiling distilled water, dried and weighed in the usual way. For every 117 grains of salt so obtained there would be 16 grains of pure sulphur; and knowing these proportions, the quantity in 100 grains of coal or coke can be at once calculated.

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* If 100 grains of finely-powdered coke be consumed in a platinum capsule over a Bunsen burner, the number of grains left will be the percentage of ash in the coke.

To find the sulphur passed off in the volatile matter of the coal, it is only necessary to treat the coke obtained from 100 grains of coal in precisely the same manner as that indicated above. The quantity so obtained is to be deducted from the previously ascertained quantity in 100 grains of coal, and the remainder will represent the sulphur volatilised during the process of distillation.

HEATING POWER OF GAS.

In consequence of the very general use of gas stoves for culinary and warming purposes, it may be as well to make a few remarks on the heating power of carburetted hydrogen gas, and the method employed to ascertain the exact amount given off during combustion. Some experiments were made in 1852 and 1853 by Mr. Lewis Thompson with this object. The apparatus employed by him was similar to the condenser previously referred to when describing the process adopted for determining the quantity of bi-sulphide of carbon in coal gas. A burner, consuming at the rate of 10 feet per hour, was placed under this condenser, so that the heated air arising from the gas in combustion was allowed to travel slowly through the worm, and thus be deprived of its surplus heat. The following table exhibits the results of observations carried on in this manner for fourteen months upon the gas supplied by three of the Metropolitan Gas Companies, from which it appears that 25 feet of gas, from Newcastle coal, will evaporate one gallon of water.

Table of observations of the calorific power of gas when consumed in a burner at the rate of 10 *cubic feet per hour.*

	Grains of water evaporated by one cubic foot of the Gas of the		
	Great Central Company.	City of London Company.	Chartered Company.
1852.			
May	2,410	2,786	——
June	2,667	2,823	2,858
July	2,795	2,870	2,886
August	2,608	2,792	2,810
September	2,676	2,820	2,614
October	2,634	2,745	2,702
November	2,660	2,805	2,822
December	2,625	2,829	2,830
1853.			
January	2,704	2,957	2,964
February	2,892	2,910	2,901
March	2,839	2,900	2,871
April	2,514	2,896	2,888
May	2,654	2,865	2,749
June	2,726	2,856	2,733
Average	2,671	2,846	2,817

From this table it appears that 30 feet, or 1 lb. in weight, of gas applied, as above explained, will evaporate 12 lbs. of water.

In a table, showing the heating power of various kinds of fuel, derived from Mr. Wicksteed's experiments, and published in the *Artizan Club Treatise on the Steam Engine*, the water evaporated by 1 lb. of the best small Newcastle coal is stated to be 8·524 lbs., and by 1 lb. of gas coke 7·908 lbs.; but from a number of experiments made by myself in 1858 with the same object, I found that 7·36 lbs. of water were evaporated by 1 lb. of coke, and 6·39 lbs. by 1 lb. of Newcastle coal. These experiments were continued for ten days, and were made with an ordinary 6-horse Cornish boiler, set in the usual way. It thus appears that 1 lb. of Newcastle coal gas will evaporate, when properly consumed, nearly twice as much water as an equal weight of either coke or coal consumed in the manner explained above.

GAS BURNERS.

In referring to the various kinds of burners used for coal gas, it must be remarked that the photogenic power of any luminiferous agent depends upon two conditions—*quantity* and *intensity*. By *quantity*, I mean that the carbonaceous particles of the flame are numerous; by *intensity*, that they are highly heated. Now the perfection of gas illumination consists in providing a burner, so constructed that these two conditions just balance each other. This subject appears to be very little understood by many burner-makers. In fact, in some experiments made recently on 15-hole Argand burners, obtained from different establishments, I have found the illuminating power of 5 feet of gas to vary as much as 50 per cent., simply through the above conditions not being properly attended to. The oxyhydrogen lime-light is an excellent example of *intensity*, the number of particles of carbon being very small, but the temperature to which they are heated very high. The *quantity* of light from a solid wick oil lamp is great, but the *intensity* is small. So that there may be great *intensity* where the *quantity* is small, or great *quantity* where *intensity* is small. If a straight wire be passed through the flame of a common candle, there will be no increase of illuminating power, because the flame of the candle already contains more solid constituents than can be satisfactorily heated by the hydrogen of the tallow; whereas with Newcastle gas, burning from an ordinary batwing or fishtail burner, exactly the reverse is the case, because the hydrogen is in excess, and the solid matter deficient. Now if the colour of the flame from a well-constructed Argand burner be compared with that from a fishtail or batwing, it will be observed that the former is brown and the latter blue, which clearly shows that the quantity of light exceeds the intensity in the Argand, whereas with the batwing or fishtail the intensity exceeds the quantity.

If the light produced from 5 feet of gas consumed in a 15-hole Argand burner, be equal to 13 candles, the light from a similar quantity of gas, consumed in a batwing or fishtail burner, will not exceed 9 candles; and the reason the batwing burner gives so bad a result, when compared with the Argand, is because there is too great a contact with the atmospheric oxygen in the lower part of the flame of the batwing; and this is easily proved by causing two flames, from batwing or fishtail burners, to impinge upon one another, and thus reduce the surface in contact with the atmosphere by nearly one-half; for, by such an arrangement as this, 5 feet of gas, consumed in a double batwing burner, gives the same amount of light as 5 feet consumed in a 15-hole Argand of the best construction. And, guided by these observations, I think it follows, that every burner has a certain fixed amount of gas which it will consume with the greatest photogenic advantage, and that when the gas is issuing from the burner at so low a pressure that the flame is just upon the point of smoking, the maximum effect for the quantity of gas consumed in that particular burner is obtained, because, in this case, the quantity and intensity of the light are so advantageously balanced, that the greatest illuminating power is the result. And, by the same reasoning, I think it also follows, that the burner best suited for the combustion of coal gas, is one in which the openings are large, so as to prevent, as much as possible, too great contact with the air in the lower part of the flame—an evil to be carefully avoided, for every one knows that an Argand burner, consuming 5 feet of gas, does not give so much light with a 9-inch chimney as with a 7-inch, because, with the former, there is a much larger supply of air than with the latter.

The laws which govern the discharge of gas through small orifices are exceedingly simple, and depend upon the specific gravity of the gas, and the pressure under which it is discharged.

The quantity of gas of the specific gravity of ·413 discharged through a ⅜ jet, under the following pressures, was as the result stated below:—

Pressure.	Gas consumed per Hour.	Pressure.	Gas consumed per Hour.
15 tenths.	31·0 feet.	3 tenths.	13·5 feet.
10 „	26·0 „	2 „	11·8 „
5 „	17·5 „	1 „	7·8 „
4 „	16·3 „		

Now, taking the standard quantity as 31 feet discharged, under 15-tenths pressure, and calculating the quantity discharged under any other pressure as the square root of that pressure, we get the following results:—

Pressure.	Gas consumed per Hour by Experiment.	Gas consumed per Hour by Calculation.
15 tenths.	31·0 feet.	——
10 „	26·0 „	25·3 feet.
5 „	17·5 „	17·8 „
4 „	16·3 „	16·02 „
3 „	13·5 „	13·8 „
2 „	11·8 „	11·4 „
1 „	7·8 „	8·0 „

Hence, it appears that the number of cubic feet of gas discharged through a small orifice,* under various pressures, is as the square root of those pressures. Similarly, it may be shown, that the quantity of gas discharged through a given orifice, under the same pressures, is as the square root of its specific gravity. This is established pretty clearly by filling an ordinary 10-feet gasholder with gases of different densities, and allowing them to blow off under similar pressures. If the time is carefully noted the truth of the above statement can be easily verified. The following results have been obtained from an experiment made in this manner:—

	Quantity Discharged.	Specific Gravity.	Time, by Observation.	Time, by Calculation.
Air . . .	10 feet.	1·000	195 seconds.	——
Cannel Gas . .	10 „	580	145 „	148 seconds.
Common Gas . .	10 „	419	120 „	126 „

The barometer at the time was 30·2 inches, and the temperature of the air 50°. The figures in the second column were, of course, corrected to the standard temperature of 60°, and barometric pressure of 30 inches.

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* It will be seen further on, in the tables of the quantities of gas discharged by ordinary gas burners, that there is a remarkable exception to this rule in the case of batwing and fishtail burners, working below six or seven-tenths pressure.

In order to make this subject more clear, and to show that the remarks I have made are founded upon the results of actual experiment, I subjoin the following tables, which I think prove satisfactorily the correctness of the observations I have made upon this part of the subject.

The following experiments were made, in 1860, with common batwing burners, Nos. 3, 4, 5, and 6. The gas, at the time tested with a 15-hole Argand burner, 7-inch chimney, consuming 5 feet per hour, gave a light equal to 14 standard candles.

Pressure.	Burner.	Quantity consumed.	Illuminating power.	Reduced to 5 feet per hour.	Value of 1 foot of Gas in Standard Candles.
25 tenths.	No. 3 Batwing.	5·5 feet.	6 candles.	5·45	1·09
20 ,,	,,	5·0 ,,	6 ,,	6·0	1·2
15 ,,	,,	4·0 ,,	5·2 ,,	6·5	1·3
10 ,,	,,	3·2 ,,	5·1 ,,	8·0	1·6
5 ,,	,,	2·0 ,,	4·2 ,,	10·5	2·1
25 tenths.	No. 4 Batwing.	7·6 ,,	9·0 ,,	5·9	1·18
20 ,,	,,	6·6 ,,	9·0 ,,	6·8	1·36
15 ,,	,,	5·5 ,,	8·0 ,,	7·2	1·45
10 ,,	,,	4·1 ,,	6·75 ,,	8·2	1·64
5 ,,	,,	2·8 ,,	5·0 ,,	8·9	1·78
25 tenths.	No. 5 Batwing.	7·9 ,,	10·5 ,,	6·6	1·32
20 ,,	,,	6·7 ,,	10·5 ,,	7·8	1·56
15 ,,	,,	5·4 ,,	9·6 ,,	8·8	1·75
10 ,,	,,	4·5 ,,	8·5 ,,	9·4	1·88
5 ,,	,,	2·6 ,,	6·0 ,,	11·5	2·30
25 tenths.	No. 6 Batwing.	12·5 ,,	9·75 ,,	3·90	0·78
20 ,,	,,	11·0 ,,	13·5 ,,	6·13	1·22
15 ,,	,,	9·5 ,,	12·5 ,,	6·57	1·31
10 ,,	,,	7·8 ,,	11·0 ,,	7·05	1·41
5 ,,	,,	5·0 ,,	9·0 ,,	9·00	1·80
2½ ,,	,,	3·0 ,,	5·5 ,,	9·17	1·83

The slits in the burners, Nos. 3, 4 and 5, were now slightly enlarged, by passing a saw through them, when the following results were obtained:—

Pressure.	Burner with enlarged Slit.	Quantity Consumed.	Illuminating Power.	Reduced to 5 feet per Hour.	Value of 1 foot of Gas in Standard Candles.
25 tenths.	No. 3 Batwing.	9·4 feet.	12·0 candles.	6·38	1·27
20 „	„	7·3 „	12·0 „	8·19	1·64
15 „	„	6·5 „	11·0 „	8·46	1·70
10 „	„	5·0 „	9·0 „	9·00	1·80
5 „	„	3·6 „	6·5 „	9·03	1·80
25 tenths.	No. 4 Batwing.	9 0 feet.	10·5 „	5·83	1·16
20 „	„	7·8 „	10·5 „	6·73	1·34
15 „	„	6·5 „	10·0 „	7·69	1·54
10 „	„	5·0 „	9·5 „	9·50	1·90
5 „	„	3·0 „	7·0 „	11·66	2·33
25 tenths.	No. 5 Batwing.	9·5 feet.	12·5 „	6·58	1·31
20 „	„	8·1 „	12·5 „	7·71	1·54
15 „	„	6·9 „	11·5 „	8·33	1·66
10 „	„	6·0 „	10·0 „	8·33	1·66
5 „	„	3·6 „	7·0 „	9·72	1·94

From an inspection of these tables, it appears that in each case when the gas was issuing with the lowest pressure, that is, when there was the least atmospheric contact with the lower part of the flame, the photogenic power was greatest; and when the gas was issuing under the heaviest pressure, and there was consequently the greatest atmospheric contact, the photogenic power was least.* This appears very conclusively in the sixth column, where, opposite five-tenths pressure in each table, it will be seen that the value of one foot of gas in standard candles far exceeds that of the same quantity of gas consumed under higher pressure.

It has been already stated that the discharge of gas through small orifices is as the square root of the pressure, but that this does not hold good with fishtail and batwing burners below six or seven-tenths pressure; for, in this case, the discharge seems to be almost directly as the pressure. In order to substantiate this remark, I subjoin the following tables of experiments made with batwing burners, consuming both Cannel and common gas, and also with a very large fishtail burner, consuming common gas only. The batwing burner employed, and which I have called No. 1, is made to consume 5 feet of Cannel gas; and it will be seen that when that quantity is consumed per hour, the greatest value for one foot of gas in standard candles is obtained; and it will also be observed that such a burner is not at all adapted for the combustion of common gas. The fishtail burner is of very large size, and might well be compared with the double batwing burner, which gives a result equal to the Argand. In constructing the following tables, a pressure-gauge was employed on which the two-hundredth of an inch is easily recorded, and the most sensitive governors were used. The gas was tested, before commencing the experiments, with a 15-hole Argand burner, and was found to equal 14 standard candles. A jet of Cannel gas was now substituted for the candle, and, after each burner had been experimented upon, this jet was compared with the standard Argand, as at the commencement. Some small variations occurred in the illuminating power of the gas, which were corrected by adjusting the jet so that the Argand burner always gave a light fourteen times larger than the jet. The results obtained, therefore, show the comparative value of the various burners examined.

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* Since the above was written, a pamphlet has been published by MM. Audouin and Bérard, in which the statement here given is fully confirmed.

Burner.	Pressure.	Illuminating Power—Standard Candles.	Value of 1 foot of Gas in Standard Candles.	Gas Consumed.	
				Actual.	Calculated.
Newcastle Gas.					
Large Fishtail.	10 tenths.	15·64	1·70	9·2 feet.	—
	9 ,,	15·16	1·78	8·5 ,,	8·73 feet.
	8 ,,	14·58	1·82	8·0 ,,	8·23 ,,
	7 ,,	16·33	2·15	7·6 ,,	7·70 ,,
	6 ,,	18 66	2·66	7·0 ,,	7·13 ,,
	5 ,,	15·98	2·57	6·2 ,,	6·50 ,,
	4 ,,	14·00	2·54	5·5 ,,	5·83 ,,
	3 ,,	10·50	2·33	4·5 ,,	5·03 ,,
	2 ,,	7·87	2·24	3·5 ,,	4·10 ,,
	1 ,,	4·66	2·02	2·3 ,,	2·91 ,,
Large Batwing, No. 1.	10 tenths.	9·5	1·58	6·0 feet.	—
	9 ,,	8·7	1·58	5·5 ,,	5·69 feet.
	8 ,,	8·0	1·54	5·2 ,,	5·36 ,,
	7 ,,	6·9	1·53	4·5 ,,	5·01 ,,
	6 ,,	6·1	1·49	4·1 ,,	4·64 ,,
	5 ,,	5·3	1·44	3·7 ,,	4·24 ,,
	4 ,,	4·5	1·45	3·1 ,,	3·79 ,,
	3 ,,	3·6	1·44	2·5 ,,	3·28 ,,
	2 ,,	2·4	1·33	1·8 ,,	2·68 ,,
	1 ,,	1·0	1·00	1·0 ,,	1·89 ,,

Burner.	Pressure.	Illuminating Power—Standard Candles.	Value of 1 foot of Gas in Standard Candles.	Gas Consumed.	
				Actual.	Calculated.
Newcastle Gas.					
Large Batwing, No. 2.	10 tenths.	14·0	1·70	8·2 feet.	——
	9 ,,	13·2	1·71	7·7 ,,	7·77 feet.
	8 ,,	12·3	1·73	7·1 ,,	7·33 ,,
	7 ,,	11·0	1·77	6·2 ,,	6·85 ,,
	6 ,,	9·8	1·78	5·5 ,,	6·35 ,,
	5 ,,	8·75	1·86	4·7 ,,	5·79 ,,
	4 ,,	7·00	1·79	3·9 ,,	5·18 ,,
	3 ,,	5·5	1·77	3·1 ,,	4·49 ,,
	2 ,,	3·7	1·68	2·2 ,,	3·66 ,,
	1 ,,	1·8	1·50	1·2 ,,	2·59 ,,
Cannel Gas.					
Large Batwing, No. 1.	10 tenths.	29·03	5·58	5·2 feet.	——
	9 ,,	25·20	5·04	5·0 ,,	4·93 feet.
	8 ,,	21·00	4·66	4·5 ,,	4·74 ,,
	7 ,,	18·43	4·39	4·2 ,,	4·34 ,,
	6 ,,	15·50	4·19	3·7 ,,	4·02 ,,
	5 ,,	13·12	4·10	3·2 ,,	3·67 ,,
	4 ,,	10·50	4·03	2·6 ,,	3·28 ,,
	3 ,,	8·00	4·00	2·0 ,,	2·74 ,,
	2 ,,	4·30	3·30	1·3 ,,	2·32 ,,
	1 ,,	2·00	2·66	0·76 ,,	1·64 ,,

The large slot Argand burner used in the following table is constructed to consume 7 feet per hour with a 7-inch chimney, and the 15-hole Argand is the ordinary Parliamentary burner, as first made in 1859.

Burner (Newcastle Gas).	Pressure.	Illuminating Power.	Value of 1 foot of Gas in Standard Candles.	Gas Consumed.	
				Actual.	Calculated.
Large Slot Argand, 7-in. chimney.	3·6 tenths.	22·00	3·14	7·0 feet.	——
	3·0 ,,	18·50	2·93	6·3 ,,	6·39 feet.
	2·5 ,,	14·25	2·64	5·4 ,,	5·83 ,,
	2·0 ,,	12·50	2·55	4·9 ,,	5·21 ,,
	1·5 ,,	9·00	2·14	4·2 ,,	4·51 ,,
	1·0 ,,	5·50	1·57	3·5 ,,	3·69 ,,
15-Hole Argand, 7-in. chimney.	0·45 tenths.	14·0	2·80	5·0 feet.	——
	0·35 ,,	10·7	2·54	4·2 ,,	4·40 feet.
	0·20 ,,	6·8	2·06	3·3 ,,	3·33 ,,
	0·09 ,,	2·6	1·17	2·2 ,,	2·24 ,,
	0·06 ,,	1·0	0·55	1·8 ,,	1·82 ,,

In comparing the results thus tabulated, it is very interesting to note the difference in the value of 1 foot of gas in standard candles when consumed in the largest sized batwing and fishtail burners. With the former, it is 1·88, with the latter, 2·66 candles. The fishtail burner, in fact, when the holes are of large diameter, is nearly equal to the double batwing, and very little behind the best results obtained from the Argand.

The following table exhibits the best results obtained from each kind of burner.

Burner (Newcastle Gas).	Pressure.	Illuminating Power.	Value of 1 foot of Gas in Standard Candles.	Gas Consumed.	
				Actual.	Calculated.
Large Argand Slot	3·6 tenths	22·00 candles.	3·14	7·0 feet.	..
15-Hole Argand ..	0·45 „	14·00 „	2·80	5·0 „	..
Double Batwing ..	3·7 „	13·75 „	2·75	5·0 „	..
Large Fishtail	6· „	18·66 „	2·66	7·0 „	7·13
Large Batwing, No. 2	5· „	8·75 „	1·86	4·7 „	5·79
Ditto No. 1	10· „	9·50 „	1·58	6·0 „	..

It is also worthy of remark that the 15-hole Argand requires less pressure to produce the maximum illuminating power than any other burner in this table.

The following table shows the comparative value of 5 feet of gas consumed by several batwing and fishtail burners, and I have also added the double batwing burner, to show the great difference in value of 5 feet of gas consumed in the combined flame, in one distinct flame, and in two separate flames—the results being respectively 13·75, 7·60, and 8·40 standard candles.

Burner (Newcastle Gas).	Pressure.	Illuminating Power.	Value of 1 foot of Gas in Standard Candles.	Gas Consumed.
Batwing Burners—				
No. 8	5·5 tenths.	9·4	1·88	5 feet.
No. 7	4·6 „	9·0	1·80	5 „
No. 6	10·5 „	8·0	1·60	5 „
No. 5	4·6 „	8·6	1·72	5 „
No. 4	9·7 „	5·7	1·14	5 „
No. 3	16·0 „	3·5	0·70	5 „
Fishtail Burners—				
No. 8	3·5 tenths.	12·1	2·42	5 feet.
No. 6	6·6 „	9·3	1·86	5 „
No. 5	8·8 „	6·3	1·26	5 „
No. 4	13·9 „	5·1	1·02	5 „
No. 3	18·0 „	2·1	0·50	4·2 „
Double Batwing.				
2. No. 5—				
Both burning	3·7 tenths.	13·75	2·75	5 feet.
One shut off......	9·0 „	7·60	1·52	5 „
Ditto	3·5 „	4·20	1·68	2·5 „

The following table is added here to show the comparative value of burners when consuming Cannel gas, from which it will be seen that burners of the Argand form, though the best for Newcastle gas, are not so favourable for the combustion of gases of high illuminating power.

Burner (Cannel Gas).	Gas Consumed.	Illuminating Power.	Reduced to 5 feet per Hour.	Value of 1 foot of Gas in Standard Candles.
No. 8 Batwing . .	5·0 feet.	31·0 candles.	31·0 candles.	6·20
30-hole Argand, 6-inch chimney . . .	4·5 „	26·5 „	29·4 „	5·88
No. 4 Fishtail . .	2·5 „	13·0 „	26·0 „	5·20
30-hole Argand, 7-inch chimney . . .	4·1 „	20·0 „	24·4 „	4·89
Leslie Burner, 3½-inch chimney . . .	3·1 „	15·0 „	24·2 „	4·83
Lava Batwing . .	2·8 „	13·5 „	24·1 „	4·82
15-hole Argand, 6-inch chimney . . .	2·8 „	11·5 „	20·5 „	4·10
No. 2 Batwing Burner .	3·0 „	12·0 „	20·0 „	4·00
15-hole Argand, 7-inch chimney . . .	3·3 „	13·0 „	19·7 „	3·94
No. 2 Fishtail . .	2·5 „	8·5 „	17·0 „	3·40

It is curious to remark that, from this table, it appears that the large batwing produces the best result when consuming Cannel gas, and is 37 per cent. superior to the 15-hole Argand Parliamentary burner; but when consuming common gas, the converse of this is the fact—the standard Argand burner will, from an inspection of the previous tables, be found to produce a light, from each cubic foot of gas, 30 per cent. superior to the large batwing. The above burners are not chosen for any particular advantages they may possess, but were merely some I happened to have by me.

By a careful consideration of all the conditions to be fulfilled, and a most elaborate series of experiments, Mr. Sugg has succeeded in constructing various kinds of Argand and other burners, which are, perhaps, superior to any others. The 15-hole Argand, with a lava top, of his manufacture, was first used by myself in photometrical observations, in February, 1859; and a similar burner was exhibited by Mr. George Lowe to the Committee of the House of Lords who sat on the Metropolis Gas Act, in 1860. This is the kind of burner now supplied by Mr. Sugg with his photometers.

ANALYSES OF COALS.

The following analyses of Cannel and bituminous coals are by Mr. Lewis Thompson, and were published in the 2nd and 3rd volumes of the *Journal of Gas Lighting.* They are reproduced here by the kind permission of the Editor of that paper.

It must be understood that in each case dry coals were operated upon, and the results of the analyses are stated in the following order:—The first column states the name of the coal; the second, its general character; the third, the percentage of volatile matter given off during distillation; the fourth, the percentage of coke left in the retort; the fifth, the percentage of ash left after burning the coal in the open air; the sixth, the nature of this ash; the seventh, eighth, and ninth, the percentage of sulphur in the coal, coke, and volatile matter respectively; and the tenth column represents the percentage of ash left after burning the coke in the open air.

ANALYSES OF CANNEL COALS.

Name of Cannel.	General Character.	Volatile Matter	Coke	Ash	Nature of Ash	Sulphur in			Ash in Coke, per cent
						Coal	Coke	Volatile Matter	
Arniston	Resembling lignite, and containing crystals of carbonate of lime, with impressions of leaves and deposits of iron pyrites. Compact. Principal fracture, slaty; cross fracture, irregular. Streak, dull brownish black. Thrown on the fire, it decrepitates, but does not fly. Colour of ash, a dirty grey; with nitrate of cobalt, greenish black. Specific gravity of coal, 1·1967.	45·5	54·5	4·18	Silicate of lime, alumina, and oxide of iron	1·70	·95	·75	7·66
Boghead	Brown, compact, and massive, containing a few impressions of sigillaria. Principal fracture, slaty, conchoidal; cross fracture, irregular. Streak, yellow. Thrown on the fire, decrepitates slightly, does not fuse, but splits. Colour of ash, white; with nitrate of cobalt, blue. Specific gravity, 1·221.	68·4	31·6	22·2	Silicate of alumina.	·53	·08	·45	70·25
Capeldrae ..	Massive, dull black, impressions of sigillaria, with deposits of carbonate of lime and pyrites. Principal fracture, conchoidal and slaty; cross fracture, distinctly conchoidal. Streak, yellowish brown. Thrown on the fire, decrepitates, splits, and flies, but does not fuse. Ash, white; with nitrate of cobalt, blue. Specific gravity, 1·2275.	54·5	45·5	10·5	Silicate of alumina.	·65	·20	·45	23·07
Kirkness	Massive and foliated, free from foreign matters. Dull brown. Principal fracture, slaty; cross fracture, conchoidal. Streak, brown. Scarcely decrepitates on the fire. Colour of ash, whitish grey; with nitrate of cobalt, dull dark blue. Specific gravity, 1·2080.	60·	40·	13·5	Silicate of alumina, lime, and oxide of iron.	1·40	·58	·82	33·7

ANALYSES OF CANNEL COALS—(*continued*).

Name of Cannel.	General Character.	Volatile Matter.	Coke.	Ash.	Nature of Ash.	Sulphur in			Ash in Coke, per Cent.
						Coal.	Coke.	Volatile Matter.	
Knightswood	Compact, dull black, massive, with deposits of carbonate of lime and iron pyrites. Principal fracture, slaty, conchoidal; cross fracture, conchoidal. Streak, shining black. Thrown on the fire, decrepitates and flies, but does not fuse. Colour of ash, pale umber; with nitrate of cobalt, dull black.	48·5	51·5	2·4	Oxide of iron and silicate of lime, with alumina.	1·10	·61	·49	4·66
Lesmahago	Massive, dull black. Principal fracture, slaty, conchoidal; cross fracture, conchoidal and angular. Streak, black and somewhat shining. Thrown on the fire, decrepitates slightly, does not split or fuse. Colour of ash, white; with nitrate of cobalt, dirty blue. Specific gravity, 1·2220.	49·6	50·4	9·1	Silicate of alumina and oxide of iron.	2·23	1·14	1·09	18·05
Lochgelly	Colour, dull black and slaty. Fracture, inclining to slaty; cross fracture, irregular conchoidal. Streak, shining black. On the fire, decrepitates and flies. Ash, white; with nitrate of cobalt, blue. Specific gravity, 1·320.	33·5	66·5	13·1	Silicate of alumina.	·75	·25	·50	29·7
Old Wemyss	Compact, dull brownish black; free from foreign matters. Principal fracture, slaty; cross fracture, angular, inclining to conchoidal. Streak, dull brownish black. Thrown on the fire, decrepitates and splits, but does not fly. Colour of ash, dull white; with nitrate of cobalt, olive green. Specific gravity, 1·3256.	52·5	47·5	15·1	Oxide of iron and silicate of alumina.	1·30	·60	·70	31·78

ANALYSES OF CANNEL COALS (*continued*).

Name of Cannel.	General Character.	Volatile Matter.	Coke.	Ash.	Nature of Ash.	Sulphur in			Ash in Coke per cent.
						Coal.	Coke.	Volatile Matter.	
WIGAN	Compact, black and shining. Principal fracture, conchoidal; cross fracture, conchoidal and cubical. Streak, shining black and waxy. Thrown on the fire, decrepitates, flies, and slightly fuses. Colour of ash, yellowish brown, inclining to red; with nitrate of cobalt, olive black. Specific gravity, 1·271.	37	63	3	Oxide of iron and silicate of alumina	1·40	·88	·52	4·76
RAMSAY'S NEWCASTLE.	Compact and massive, slightly tinged with oxide of iron. Black and shining. Principal fracture, highly conchoidal and resinoid; cross fracture, conchoidal and cubical. Thrown on the fire, decrepitates and flies to pieces, inclined to fuse. Colour of ash, reddish brown; with nitrate of cobalt, dull black. Specific gravity, 1·200.	36·8	63·2	6·6	Oxide of iron and silicate of lime, with alumina.	1·75	·94	·81	10·44
BAND OF CANNEL IN ***Leverson's Wallsend Coal.***	This is a dull black band, which runs through the mass of the coal. *Fracture*, slaty, conchoidal; cross fracture, cubical and conchoidal. *Streak*, black and shining. On the fire, splits, but does not fly or fuse. Ash, dull white, with shade of pink; with nitrate of cobalt, dull black. Specific gravity, 1·320.	39·8	60·2	8·35	Oxide of iron and silicate of lime, with alumina.	1·00	·50	·50	13·87
BAND OF CANNEL IN ***Pelton Main Coal.***	Colour, dull black, with a shade of brown. *Structure*, compact and uniform. *Fracture*, conchoidal and slaty; cross fracture, irregular, conchoidal, with deposits of iron pyrites. *Streak*, black and shining. On the fire, splits, but does not fly; agglutinates and intumesces slightly. Ash, dirty white, with shade of pink; by nitrate of cobalt, black. Specific gravity, 1·320.	31·5	68·5	9·4	Oxide of iron and silicate of lime, with alumina.	·85	·40	·40	13·7

ANALYSES OF CANNEL COALS—(*continued*).

Name of Cannel.	General Character.	Volatile Matter.	Coke.	Ash.	Sulphur in			Ash in Coke, per Cent.
					Coal.	Coke.	Volatile Matter.	
Band of Cannel in *Washington Coal.*	This resembles the Pelton and Leverson's bands. Colour, dull brownish black. Fracture, irregular, conchoidal; cross fracture, cubical and conchoidal. Streak, shining black. On the fire, splits and fuses slightly. Ash, dirty white, with shade of pink. Specific gravity, 1·326.	27·4	72·6	9·37	1·10	·56	·54	12·9
Staffordshire	Compact and uniform. Fracture, in all directions conchoidal, with deposits of carbonate of lime. Streak, shining black. On the fire, decrepitates and flies, but does not fuse. Ash, dirty white. Specific gravity, 1·220.	50·	50·	2·9	1·30	·52	·78	5·8
New Brunswick ..	Jet black, and pitchy looking. Fracture, highly conchoidal and resinoid in all directions. Streak, dull and pitchy. On the fire, cracks and splits, then fuses and boils up with strong intumescence. Largely soluble in naphtha, oil of turpentine, and bisulphuret of carbon. Specific gravity, 1·098. The coke is light and friable, like that from pitch.	66·3	33·7	·6	·07	None.	·07	1·78

ANALYSES OF BITUMINOUS COALS.

Name of Coal	General Character	Volatile Matter	Coke	Ash	Sulphur in			Ash in Coke, per Cent.
					Coal	Coke	Volatile Matter	
Cheshire—								
Harecastle........	Structure laminated, with numerous black bands. Principal fracture, slaty, inclining to angular; cross fracture, cubical, with deposits of carbonate of lime and iron pyrites. Streak, dull black. On the fire, agglutinates a little. Ash, dirty red. Specific gravity, 1·230.	31·5	63·5	5·	2·10	1·10	1·00	7·3
Cumberland—								
Cumberland, No. 1	Dull black, and coarse grained. Fracture, rough and hackley, inclining to cubical; cross fracture, slaty and angular. Streak, dull black. On the fire, agglutinates and swells a little. Ash, dirty white. Specific gravity, 1·294.	25·5	74·5	2·1	1·30	·70	·60	2·8
Cumberland, No. 2	Coal black, with dull laminæ. Fracture, irregular, inclining to cubical; cross fracture, rough and angular, with charcoal deposits. Streak, black. On the fire, swells and fuses slightly. Ash, grey. Specific gravity, 1·275.	25·6	74·4	1·4	1·10	·60	·50	1·9
Cumberland, No. 3	Coal black, and coarse grained, semi-crystalline. Fracture, hackley and angular, with layers of charcoal; cross fracture, irregular and angular. Streak, brownish black. On the fire, swells and agglutinates. Ash, yellow white. Specific gravity, 1·290.	30·0	69·1	4·	1·70	·80	·90	5·8

ANALYSES OF BITUMINOUS COALS—(*continued*).

Name of Coal.	General Character.	Volatile Matter.	Coke.	Ash.	Sulphur in			Ash in Coke, per Cent.
					Coal.	Coke.	Volatile Matter.	
Derbyshire— *Staveley*..........	Colour, jet black. Structure, splintry and prismatic. Fracture, slaty and columnar; cross fracture, irregular and cubical, with deposits of carbonate of lime and iron pyrites. Contains several black bands with charcoal. Streak, black. On the fire, crackles and splits; fuses slightly. Ash, dirty pale red. Specific gravity, 1·275.	40·9	59·1	2·7	1·20	·80	·40	4·57
Gloucestershire— *Coal-pit Heath*....	Colour, coal black. Structure, granular and crystalline. Fracture, coarse grained and irregular in all directions, with numerous layers of charcoal and iron pyrites, and traces of carbonate of lime. On the fire, swells and fuses slightly. Ash, brick red. Specific gravity, 1·370.	30·1	69·9	5·8	4·10	2·20	1·90	8·3
Whitecroft, near Lydney........	Coarse grained and fibrous. Principal fracture, hackley and slaty, with deposits of charcoal; cross fracture, uneven, inclining to rhomboidal, with deposits of carbonate of lime and iron pyrites. Streak, dull black. On the fire, fuses slightly. Ash. deep red. Specific gravity, 1·401.	34·3	65·7	11·1	3·10	1·90	1·20	16·8
Lancashire— *Arley*............	Colour, coal black, with shining layers. Structure, massive. Fracture, inclining to slaty, with charcoal deposits; cross fracture, cubical, with traces of carbonate of lime. On the fire, spits slightly, and intumesces. Ash, dull fawn colour. Specific gravity, 1·270.	33·7	66·3	3·6	1·20	·60	·60	4·8

ANALYSES OF BITUMINOUS COALS—(*continued*).

Name of Coal.	General Character.	Volatile Matter.	Coke.	Ash.	Sulphur in			Ash in Coke, per Cent.
					Coal.	Coke.	Volatile Matter.	
LANCASHIRE— *St. Helen's*	Coal black and laminated. Principal fracture, slaty; cross fracture, cubical, with numerous deposits of charcoal in the principal fracture, and carbonate of lime in the cross fracture. Streak, dull black. On the fire, swells and agglutinates. Ash, fawn colour. Specific gravity, 1·285.	37·2	62·8	1·2	1·10	·54	·56	1·91
NORTHUMBERLAND AND DURHAM— *Blenkinsopp*	Coal black; laminated. Fracture, coarse and granular; cross fracture, splintry, inclining to cubical. Streak, dull black. On the fire, fuses slightly and intumesces. Ash, grey. Specific gravity, 1·298.	38·	62·	5·1	1·60	·80	·80	8·2
Dean's Primrose ..	Colour, brownish black, with shining layers. Fracture, in all directions, cubical and somewhat irregular, with occasional deposits of iron pyrites. On the fire, splits, and crackles slightly, swells, and intumesces. Ash, brick red. Specific gravity, 1·261.	29·25	70·75	2·4	1·40	·71	·69	3·4
Garesfield (*Butes'*)	Coal black and rather friable, with thin bands of dark laminæ throughout. Fracture, uneven and cubical; cross fracture, angular and hackley, containing traces of charcoal. Streak, dull black. On the fire, swells and fuses together. Ash, light red. Specific gravity, 1·290.	28·3	71·7	3·2	·90	·40	·50	4·4

ANALYSES OF BITUMINOUS COALS—(*continued*).

Name of Coal.	General Character.	Volatile Matter.	Coke.	Ash.	Sulphur in			Ash in Coke, per Cent.
					Coal.	Coke.	Volatile Matter.	
Northumberland and Durham—								
Garesfield (*Cowan's*)	Coal black and shining, with thin dark laminæ. Fracture, irregular and cubical; cross fracture, angular, and affording deposits of charcoal. Streak, dull black. On the fire, aggluminates, swells, and partially fuses. Ash, pale cream colour. Specific gravity, 1·259.	29·4	70·6	·95	·85	·40	·45	1·3
Gosforth	Coal black, with shining layers. Fracture, irregular, inclining to cubical; cross fracture, cubical, with indications of charcoal. Streak, dull black. On the fire, swells and agglutinates. Ash, dull yellow. Specific gravity, 1·260.	35·	65·	1·	1·10	·50	·60	1·5
Hastings Hartley ..	Jet black; laminated, and splintry. Fracture, cubical, and slightly conchoidal; cross fracture, cubical and irregular. Streak, black, with a shade of brown. On the fire, cracks and splits, with a trifling tendency to agglutinate. Ash, white, with red streaks. Specific gravity, 1·278.	36·6	63·4	2·	·95	·50	·45	3·1
West Hartley	Jet black, with thin dull laminæ in the direction of the principal fracture, and slight deposits of charcoal. Fracture, slaty, cubical, inclining to conchoidal; cross fracture, cubical, with layers of carbonate of lime. Streak, brown black. On the fire, splits and opens, but does not fuse. Ash, dull cream colour. Specific gravity, 1·269.	35·8	64·2	4·7	1·10	·60	·50	7·3

ANALYSES OF BITUMINOUS COALS—(*continued*).

Name of Coal.	General Character.	Volatile Matter.	Coke.	Ash.	Sulphur in			Ash in Coke, per Cent.
					Coal.	Coke.	Volatile Matter.	
LANCASHIRE—								
St. Helen's	Coal black and laminated. Principal fracture, slaty; cross fracture, cubical, with numerous deposits of charcoal in the principal fracture, and carbonate of lime in the cross fracture. Streak, dull black. On the fire, swells and agglutinates. Ash, fawn colour. Specific gravity, 1·285.	37·2	62·8	1·2	1·10	·54	·56	1·91
NORTHUMBERLAND AND DURHAM—								
Blenkinsopp	Coal black; laminated. Fracture, coarse and granular; cross fracture, splintry, inclining to cubical. Streak, dull black. On the fire, fuses slightly and intumesces. Ash, grey. Specific gravity, 1·298.	38·	62·	5·1	1·60	·80	·80	8·2
Dean's Primrose ..	Colour, brownish black, with shining layers. Fracture, in all directions, cubical and somewhat irregular, with occasional deposits of iron pyrites. On the fire, splits, and crackles slightly, swells, and intumesces. Ash, brick red. Specific gravity, 1·261.	29·25	70·75	2·4	1·40	·71	·69	3·4
Garesfield (*Butes'*)	Coal black and rather friable, with thin bands of dark laminæ throughout. Fracture, uneven and cubical; cross fracture, angular and hackley, containing traces of charcoal. Streak, dull black. On the fire, swells and fuses together. Ash, light red. Specific gravity, 1·290.	28·3	71·7	3·2	·90	·40	·50	4·4

ANALYSES OF BITUMINOUS COALS—(*continued*).

Name of Coal.	General Character.	Volatile Matter.	Coke.	Ash.	Sulphur in			Ash in Coke, per Cent.
					Coal.	Coke.	Volatile Matter.	
Northumberland and Durham—								
Garesfield (Cowan's)	Coal black and shining, with thin dark laminæ. Fracture, irregular and cubical; cross fracture, angular, and affording deposits of charcoal. Streak, dull black. On the fire, aggluminates, swells, and partially fuses. Ash, pale cream colour. Specific gravity, 1·259.	29·4	70·6	·95	·85	·40	·45	1·3
Gosforth	Coal black, with shining layers. Fracture, irregular, inclining to cubical; cross fracture, cubical, with indications of charcoal. Streak, dull black. On the fire, swells and agglutinates. Ash, dull yellow. Specific gravity, 1·260.	35·	65·	1·	1·10	·50	·60	1·5
Hastings Hartley ..	Jet black; laminated, and splintry. Fracture, cubical, and slightly conchoidal; cross fracture, cubical and irregular. Streak, black, with a shade of brown. On the fire, cracks and splits, with a trifling tendency to agglutinate. Ash, white, with red streaks. Specific gravity, 1·278.	36·6	63·4	2·	·95	·50	·45	3·1
West Hartley	Jet black, with thin dull laminæ in the direction of the principal fracture, and slight deposits of charcoal. Fracture, slaty, cubical, inclining to conchoidal; cross fracture, cubical, with layers of carbonate of lime. Streak, brown black. On the fire, splits and opens, but does not fuse. Ash, dull cream colour. Specific gravity, 1·269.	35·8	64·2	4·7	1·10	·60	·50	7·3

ANALYSES OF BITUMINOUS COALS—(*continued*).

Name of Coal.	General Character.	Volatile Matter.	Coke.	Ash.	Sulphur in			Ash in Coke, per Cent.
					Coal.	Coke.	Volatile Matter.	
NORTHUMBERLAND AND DURHAM—								
Leverson's Wallsend	Colour, coal black, with shining layers. Fracture, cubical, and slightly slaty; cross fracture, cubical, with thin layers of iron pyrites. Streak, black and shining. On the fire, opens out, and agglutinates. Ash, brick red. Specific gravity, 1·278.	34·9	65·1	4·9	1·30	·65	·65	7·52
South Peareth	Dull black, with bright laminæ, coarse grained. Fracture, irregular, hackley, and inclining to cubical, with charcoal deposits; cross fracture, cubical. Streak, dull black. On the fire, intumesces and fuses partially. Ash, light yellow. Specific gravity, 1·266.	27·8	72·2	1·8	1·20	·60	·60	2·5
Pelaw Main	Colour, coal black, inclining to jet in variable layers. Fracture, cubical in all directions, with deposits of pyritic charcoal and carbonate of lime. On the fire, opens out, agglutinates, and intumesces. Ash, pale fawn colour. Specific gravity, 1·271.	30·3	69·7	2·60	1·20	·70	·80	3·7
Pelton Main	Colour, coal black, with shining layers. Fracture, in both directions cubical, with thin deposits of carbonate of lime, and iron pyrites in the cross fracture. Streak, black and shining. On the fire, opens out, and fuses slightly. Ash, pale ochry yellow. Specific gravity, 1·270.	28·4	71·6	1·41	1·10	·62	·48	1·96

ANALYSES OF BITUMINOUS COALS—(*continued*).

Name of Coal.	General Character.	Volatile Matter.	Coke.	Ash.	SULPHUR IN			Ash in Coke, per Cent.
					Coal.	Coke.	Volatile Matter.	
NORTHUMBERLAND AND DURHAM—								
New Pelton	Colour, coal black, inclining to jet in layers. Fracture, slaty and cubical; cross fracture, irregular and cubical. Streak, black and shining. On the fire, opens out, fuses slightly, and intumesces. Ash, light brick red. Specific gravity, 1·265.	30·2	69·8	1·75	1·10	·56	54·	2·5
South Tyne	Shining black, with dull laminæ. Fracture, somewhat rhomboidal and irregular, with layers of charcoal and pyrites; cross fracture, angular. Streak, dull brownish black. On the fire, agglutinates and swells slightly. Ash, deep pink. Specific gravity, 1·339.	36·3	63·7	3·9	2·10	1·10	1·00	6·1
Urpeth	Colour, coal black, with shining layers. Fracture, in all directions, cubical, with layers of carbonate of lime and iron pyrites on the cross fracture. Streak, black and shining. On the fire, opens out, swells, and fuses slightly. Ash, dull ochry yellow. Specific gravity, 1·271.	28·7	71·3	1·35	1·00	·60	·40	1·89
Washington	Colour, coal black, with shining layers. Fracture, in all directions, cubical and irregular. On the fire, opens out and fuses slightly. Streak, shining black. Ash, reddish yellow. Specific gravity, 1·260.	31·25	68·75	2·2	1·30	·67	·63	3·2

ANALYSES OF BITUMINOUS COALS—(*continued*).

Name of Coal.	General Character.	Volatile Matter.	Coke.	Ash.	SULPHUR IN			Ash in Coke, per Cent.
					Coal.	Coke.	Volatile Matter.	
SOMERSETSHIRE— *Nailsea*	Dull black, coarse grained, and fibrous. Fracture, hackley, inclining to rhomboidal, with numerous deposits of charcoal and iron pyrites; cross fracture, very irregular. Streak, brown black. On the fire, swells and fuses together. Ash, flesh-coloured, with red streaks. Specific gravity, 1·312.	34·9	65·1	3·	2·85	1·50	1·35	4·6
Radstock	Colour, dull black. Structure, coarse grained and irregular. Fracture, slightly slaty; cross fracture, hackley, inclining to cubical, with layers of charcoal and iron pyrites, in cubical crystals; deposits of carbonate of lime. Streak, dull black. On the fire, alters but little, and intumesces slightly. Ash, dull yellow and floculent. Specific gravity, 1·275.	38·25	61·75	3·5	3·10	1·80	1·30	5·6
STAFFORDSHIRE— *Apedale, 4 Feet*....	Jet black, and in square, splintry fragments. Principal fracture, slaty, and slightly conchoidal; cross fracture, irregular, and numerous black bands. On the fire, decrepitates and opens; does not fuse. Ash, deep fawn colour. Specific gravity, 1·267.	40·	60·	·75	·80	·38	·42	1·25

ANALYSES OF BITUMINOUS COALS—(*continued*).

Name of Coal.	General Character.	Volatile Matter.	Coke.	Ash.	Sulphur in			Ash in Coke, per Cent.
					Coal.	Coke.	Volatile Matter.	
Staffordshire—								
Apedale..........	Jet black and laminated; splintry and hard. Principal fracture, slaty; cross fracture, irregular and angular, inclining to cubical. Streak, shining black. On the fire, crackles and burns freely, but remains open, without any symptoms of fusion. Ash, deep red. Specific gravity, 1·307.	38·5	61·5	1·9	1·50	·82	·68	3·1
Heathern	Colour, dull black, with shining layers. Fracture, slaty, containing deposits of charcoal; cross fracture, cubical, with thin layers of carbonate of lime and iron pyrites. On the fire, splits and fuses slightly. Ash, pale dull yellow. Specific gravity, 1·280.	42·9	57·1	1·75	1·50	·70	·80	
Silverdale, 10 *Ft*...	Splintry and laminated. Principal fracture, slaty; cross fracture, angular, and slightly conchoidal. Streak, dull black. On the fire, splits and crackles slightly; does not fuse. Ash, dull red. Specific gravity, 1·301.	34·	66·	1·95	1·30	·70	·60	2·92
Woodshutts, 7 *Ft*., *Banbury*	Fibrous and coarse grained. Principal fracture, hackley; cross fracture, irregular, inclining to rhomboidal, with layers of charcoal. On the fire, swells, but does not fuse. Ash, deep fawn colour. Specific gravity, 1·291.	40·2	59·8	1·22	·90	·54	·36	2·03

ANALYSES OF BITUMINOUS COALS—(*continued*).

Name of Coal.	General Character.	Volatile Matter.	Coke.	Ash.	Sulphur in			Ash in Coke, per Cent.
					Coal.	Coke.	Volatile Matter.	
Wales (North)—								
Ruabon, Top Yard Seam	Coal black, with shining layers; laminated. Fracture, slaty and cubical, with charcoal deposits; cross fracture, cubical. Streak, black. On the fire, swells and agglutinates. Ash, pale fawn colour. Specific gravity, 1·269.	37·5	62·5	2·5	1·40	·80	·60	4·
Ruabon, Main Coal	Coal black, and laminated. Fracture, irregular, inclining to cubical; cross fracture, foliated and splintry, with numerous layers of charcoal, and some indications of iron pyrites. Streak, dull black. On the fire, swells and fuses together. Ash, pale yellow. Specific gravity, 1·284.	41·5	58·5	1·	·85	·45	·40	1·7
Ruabon, Yard Seam	Coal black, with dull laminæ. Fracture, irregular, inclining to cubical; cross fracture, angular, with considerable deposits of charcoal, and thin layers of carbonate of lime. Streak, dull black. On the fire, agglutinates and intumesces. Ash, fawn colour. Specific gravity, 1·271.	34·	66·	1·4	1·10	·60	·50	2·1
Ruabon, Nant Seam	Shining black, and in columnar concretions. Fracture, coarse and hackley, with charcoal deposits; cross fracture, rhomboidal and crystalline, with thin layers of carbonate of lime. Streak, black. On the fire, agglutinates slightly and intumesces. Ash, cream colour. Specific gravity, 1·269.	37·9	62·1	1·4	1·10	·70	·40	2·2

ANALYSES OF BITUMINOUS COALS—(*continued*).

Name of Coal.	General Character.	Volatile Matter.	Coke.	Ash.	Sulphur in			Ash in Coke, per Cent.
					Coal.	Coke.	Volatile Matter.	
Wales (South)—								
Rhonda	Colour, coal black. Structure, coarse grained. Fracture, slaty and irregular; cross fracture, hackley and angular. On the fire, swells slightly. Ash, light fawn colour. Specific gravity, 1·278.	22·8	77·2	2·7	2·30	1·20	1·10	3·5
Rhonda, Low Main	Colour, coal black; coarse grained and hackley. Fracture, irregular and slightly cubical; cross fracture, rough and angular. Streak, dull black. On the fire, intumesces and agglutinates feebly. Ash, pale red. Specific gravity, 1·280.	23·1	76·9	2·1	2·20	1·10	1·10	2·7
Yorkshire—								
Elsecar Low Pit ..	Colour, jet black, with dull layers. Structure, laminated. Fracture, slaty, inclining to cubical; cross fracture, cubical, with numerous deposits of charcoal, and traces of carbonate of lime. Streak, black. On the fire, swells and fuses with some intumescence. Ash, ochry yellow. Specific gravity, 1·258.	37·	63·	1·1	1·20	·63	·57	1·74
Grigleston Cliff, Soft	Colour, coal black. Structure, splintry, and in layers. Fracture, slaty, with bands of charcoal; cross fracture, hackley and cubical, containing traces of carbonate of lime. Streak, black. On the fire, alters but little, and does not fuse or decrepitate. Ash, brick red. Specific gravity, 1·255.	35·6	64·4	1·6	1·40	·75	·65	2·48

ANALYSES OF BITUMINOUS COALS—(*continued*).

Name of Coal.	General Character.	Volatile Matter.	Coke.	Ash.	Sulphur in			Ash in Coke, per Cent.
					Coal.	Coke.	Volatile Matter.	
Yorkshire—								
Mortomly	Coal black, with shining layers, in splintry fragments. Fracture, laminated and cubical; cross fracture, cubical and irregular. Streak, dull black. On the fire, splits and opens, but afterwards agglutinates and intumesces. Ash, light fawn colour. Specific gravity, 1·220.	37·	63·	1·6	1·10	·60	·50	2·5
Silkston, No. 1....	Colour, jet black. Structure, laminated and prismatic. Fracture, slaty; cross fracture, cubical and irregular, with deposits of carbonate of lime and charcoal. Streak, black and shining. On the fire, splits and fuses slightly. Ash, fawn colour. Specific gravity, 1·260.	34·1	65·9	2·78	1·30	·80	·50	4·2
Silkston, No. 2....	Colour, jet black. Structure, uniform. Fracture, in all directions cubical; traces of carbonate of lime and charcoal. Streak, brownish black. On the fire, fuses slightly, and intumesces. Ash, yellowish fawn colour. Specific gravity, 1·259.	38·	62·	2·55	1·10	·60	·50	4·1
Silkston, *No.* 3....	Colour, coal black. Structure, laminated and prismatic. Fracture, slaty and columnar; cross fracture, irregular and cubical, with deposits of charcoal and traces of carbonate of lime. Streak, black. On the fire, alters little. Ash, pale fawn colour. Specific gravity, 1·262.	35·2	64·8	2·8	1·45	·75	·70	4·

ANALYSES OF BITUMINOUS COALS—(*continued*).

Name of Coal.	General Character.	Volatile Matter.	Coke.	Ash.	Sulphur in			Ash in Coke, per Cent.
					Coal.	Coke.	Volatile Matter.	
Yorkshire— *Soap House Pit*	Dull black and slaty, with impressions of leaves. Fracture, rough and hackley, inclining to conchoidal; cross fracture, irregular and angular. On the fire, splits, and then agglutinates and swells. Streak, dull brownish black. Ash, light brown. Specific gravity, 1·258.	35·	65·	·8	·75	·40	·35	1·2
Woodthorp	Compact, black and uniform in appearance; resembles Cannel coal. Fracture, conchoidal; cross fracture, splintry and conchoidal, with layers of carbonate of lime. Streak, black. On the fire, decrepitates slightly and splits, but does not fuse. Ash, dirty pink. Specific gravity, 1·347.	33·1	66·9	10·5	1·20	·70	·50	16·6
France— *Denain* (*Valenciennes*)	Colour, coal black. Structure, coarse grained and slightly fibrous. Fracture, irregular, inclining to cubical, with layers of charcoal; cross fracture, hackley and angular, with traces of iron pyrites. On the fire, but little affected, intumesces and agglutinates. Ash, fawn colour. Specific gravity, 1·265.	29·9	70·1	6·	2	1·30	1·10	8·57